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THESIS

Development of Computer-Aided Instruction Systems to Facilitate Reading Skills of Learning-Disabled Children

by

Patricia M. Anderson

December 1993

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This approach identifies and discusses the fundamental concepts of learning, motivation, learning disabilities, the Theory of Multiple Intelligences, computer games, and intelligent computer-aided learning (ICAL). These concepts are then integrated into the design of a model that manipulates these concepts to teach reading skills.

The result of this effort is CAPER (Computer-Assisted Personal Education Resource). It is a model of a system that will: a) identify the individual's dominant learning styles, b) tailor the instruction and presentation to those styles, and c) present the lessons in an interactive game-like style that will retain the child's interest and enhance the learning process.

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Development of Intelligent Computer-Assisted Instruction Systems to Facilitate Reading Skills of Learning-Disabled Children

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requirements for the degree of

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ABSTRACT

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I. INTRODUCTION

Since Kirk coined the term "learning disabled" (LD) in 1963 (KIRK 81, p. 7), millions of children have been classified as LD for many reasons. Some children have personality or physical control problems that are too disruptive for the average classroom. Others have physical or brain dysfunctions that hinder or prevent normal learning. However, many of these children simply do not learn fast enough in the typical classroom to keep pace with their peer group. Gardner's Theory of Multiple Intelligences (GARDN 83, pp. 73 - 327) explains how these intelligent children fall so far behind in the classroom: It is not that they cannot learn; it is that their style of learning is incompatible with the predominant teaching style in the average American classroom. The automated teaching system model described in this thesis is specifically designed to help these students keep pace with their peers, avoid the stigma of being labeled "learning disabled," and return special education resources to the children that really need them.

An intelligent tutoring computer system can be an excellent tool for teaching a student that is having trouble keeping up. This system can be designed with a wide variety of input devices, graphics, animation, and sound so that it can be used by children who can not yet read. The system accepts variable responses to the student's inputs, from patient to high pressure. The displays can be soothing and supportive or highly stimulating and demanding. The power of the system model described herein is that it can vary as needed by the individual student. The system will automatically diagnose the students learning style and preferences and modify its presentation in the optimum style for that child.

The following sections briefly explain what LD means, what Intelligent Computer-Assisted Learning (ICAL) systems are, and how they can help many of the children that are labeled LD learn, and what needs to be done to develop such systems.

A. THE LEARNING-DISABLED CHILD

To understand how ICAL systems can help educate learning-disabled children, the reader must first understand what LD means and some of the controversy surrounding the special education community. The term LD was first used by Kirk in 1963 to describe "children who have disorders in development of language, speech, reading, and associated communication skills (KIRK 81, p. 7)." Since then, millions of children have been labeled learning-disabled. This label is most often applied after the student has shown a lack of progress in a regular classroom, and then performed poorly on tests designed to evaluate learning-disabilities. One major criticism is that "Most of these tests demand that children do things they've never done before, would never choose to do on their own, and will never do again. Yet on the basis of their performance, these tests (are used to) classify children as either normal or disabled learners" (ARMST 87, p. 29). San Diego State University sociologist Hugh Mehan and his colleagues observed learning disability specialists use a "test until find" approach in their work. The child is tested until the testers locate a suspected disability, then they stop testing and label the child. (ARMST 87, p. 31) (MEHAN 86, p. 100) The child is then placed in a special class where the notion that he is learning disabled is reinforced and all attention is focused on his disability and not on his strengths. According to the literature, all too often he receives more of the same worksheets and drills that he had trouble with in the first place instead of alternate methods of teaching. Placement "in special programs tends to be a self-validating, one-way process from which there is no return. Once the placement is made, and once the label is attached, both are usually permanent." (SCHRA 75, p. 117)

The special education community labels millions of children as learning-disabled, yet "the experts seem to be no closer to defining what it means, let alone to finding a cure for it (ARMST 87, p. 7)" (ARMST 93, p. 170) (SCHRA 75, pp. 30-67). According to Algozzine, "No one ... has been able to demonstrate to me that a specific, distinctly unique group of behaviors differentiate LD children from many of their classmates (TUCKE 83)." Ross comments that "A learning-disabled child is neither damaged nor permanently

impaired. The disability is an inability to make use of the lack of specialized instruction usually found in the typical classroom. Given proper and specialized instruction, the disability disappears. The problem is thus an educational problem, not a psychological problem or a medical problem." (ROSS 77, p. 11) A teacher can not develop twenty to thirty unique learning programs for a class, but the program proposed in this thesis can.

Why would a child be tested in the first place? Usually, the child's teacher recommends him for evaluation because he isn't doing the assigned classroom work well. He has difficulty paying attention. He's constantly moving around. He doesn't complete his worksheets. Basically, he doesn't do what teachers want him to do to maintain good order and discipline in the classroom. This behavior does not mean the child is learning-disabled; it may only indicate that the child has difficulty learning in that specific environment or format. He has his own unique learning style that doesn't work in the classrooms structured around the linguistic and mathematical/logical learning styles.

Tarver and her colleagues at the University of Wisconsin's School of Education found that learning-disabled children scored higher than normal children on tests of non-verbal creativity. Although they had higher verbal scores in the first grade, their verbal skills decreased as they progressed to higher grades (ARMST 87, p.8). These children tend to be better at spatial tasks than the average child, and not as good at sequential tasks. United States public schools are most successful when teaching children who operate sequentially, not spatially. It is possible, though it requires more work, to teach in a way that appeals to the strengths of all children. Gardner has developed a theory, illustrated in the Seven Intelligences Model and explained in Chapter II, that there are many children with non-sequential learning styles that are improperly labeled as being learning-disabled just because they have difficulty learning in the do-your-worksheet-and-wait atmosphere that exists in so many classrooms today (GARDN 83, pp. 73-327). Educators need new, flexible tools to enable them to be proactive and determine how they can help the children learn instead of placing them in a special education class. Once in a special education class, many bright children will live down to the lower expectations. Children learn in many different

ways. Is there a way to modify our education system which allows children to learn using all their talents and gifts? This thesis presents one such approach.

B. ALTERNATE LEARNING STYLES

Intelligent Computer-Assisted Learning (ICAL) systems use computers to present educational material to the user in the forms of drills, exercises, or tutorial sequences in a way that enables the user, rather than the computer, to choose the format of the learning. An ICAL system allows the flexibility to adapt to each individual user.

A school classroom typically does not have enough flexibility to meet the needs of all of the children. One teacher cannot effectively meet the varying needs of 30 or more diverse students all at one time. Computer systems can be used to supplement the instruction given in school. If the ICAL system is properly developed, it can monitor and evaluate user choices and answers, and then modify itself to adapt to the different learning styles and preferences of each user. This will allow each student to use his or her strongest learning techniques instead of the ones that conveniently lend themselves to pencil and paper. Thus, the students can learn the necessary information while still having fun, an important motivational factor for superior retention and understanding.

Berger points out (BERGE 93, p. 36) that television advertisers have "learned to use video-game visual techniques, computer techniques - all the things that kids respond to." Papert says (BRAND 87, p. 123):

> It's a total love affair between kids and computers. (Children want) to control an important part of the world. They're always reaching out to grab what is perceived as important in the adult world. They grab a pencil and scribble with it. They can feel the flexibility of the computer and its power. They can find a rich intellectual activity with which to fall in love. It's through these intellectual love affairs that people acquire a taste for rigor and creativity. And they can see games right away that are fun to play.

Advertisers are smart enough to take advantage of this love affair to sell products. It is possible to adapt the advertisers' methods to educating children. It's a very highly motivating medium that can be programmed to help all children.

Once a child's "love affair" with computers is established, they do almost anything on it. As Albert Einstein said, "Love is a better teacher than duty." Teachers can take advantage of that love affair just like the advertisers do. The computer program can be designed to assess how the child likes to play with the computer through a series of interactions feeding an expert system engine. This will determine the childs learning style. The child will then be presented with the lesson for the day in a format consistent with the identified learning style. The child will then eagerly cover the material presented, will pay attention because he is engrossed with the computer, and will remember the material more easily because it can be presented in many ways (visually, auditory, musically...). The computer can also be programmed to evaluate responses given, and to make modifications in the student's preferences. The program can dynamically modify it's presentation to ensure the material is mastered, but constantly present it in a way that the child enjoys it (unlike the worksheets children do daily in regular classroom settings which are preprinted and difficult to modify). With an ICAL system such as this, the computer can adapt to each individual child and their preferences for the session, which may change from day to day. The computer doesn't have to teach 20 or more students at one time in a static, non-stimulating classroom environment. As a result, more children can be motivated to learn, will learn, and many fewer will be labeled unnecessarily because they fail to fit into the standard classroom model.

Alan Lesgold, chairman of a special conference concerning the future of computers in education and the research needed to realize the computer's potential, stated:

> If we are to realize the potential of computer technology for helping students develop as readers and writers, we need research of several kinds. First, we need to understand what motivates students to become active readers and writers, and we need to understand how computers can be used to support these interests and not limit them. We need certain types of computer science research that explores the uses of computer technology in diagnosing individual student's difficulties with reading and writing, and the use of computers in helping students overcome problems. (LESGO1 83, p. 246)

This thesis answers some of those questions and offers a possible solution.

C. THESIS ORGANIZATION

Chapter II examines how the learning process works. Chapter III adapts the theories and models of the learning process to different learning styles. Chapter IV adapts Chapter III's results to computers. Chapter V provides the detailed discussion of how CAPER employs several expert system modules to produce a system that interprets each student's needs and abilities and tailors a unique lesson plan for that student. CAPER then presents the lesson and modifies the presentations as the student progresses through the program. Chapter VI provides a detailed example of CAPER with detailed explanations of how learning theory and the seven intelligences are applied. Chapter VII summarizes the accomplishments and offers conclusions and recommendations for future work.

II. THE LEARNING PROCESS

In systems analysis, it is understood that the more fully the programming and analysis team understands the subject area, the more effective the objective system will be. This chapter will examine some of the key elements of the learning process to help provide a base level understanding to be built upon during the design phase in later chapters. This chapter will first discuss the motivation needed for learning, and then cover learning itself. It will then focus on Gardner's Theory of Multiple Intelligences to look at various ways people learn. The remainder of this thesis develops a computer program that employs the theory to teach children to read.

A. MOTIVATION

Motivation is that characteristic that makes someone want to do something (CRAWF 81, pp. 13-14) (ERVIN 79, p.17) (SMITH 86, p.46). If an individual wants to learn, he is interested and motivated to learn. Motivation affects what we remember (KOSSL 92, p.345) and is clearly a critical part of the learning process. Since motivation is important in the learning process, it is essential that it be considered when developing a learning tool. There are several ways to enhance the motivational aspects of an activity.

If people engage in an activity for its own sake, then it is intrinsically motivating. The activity can also be described as fun, interesting, captivating, or appealing. Challenge, fantasy and curiosity are some of the qualities that make an activity intrinsically motivating. (MALON 84, p. 69)

Csikszentmohalyi describes the characteristics that make activities intrinsically motivating:

1. The activity should be structured so that the actor can increase or decrease the level of challenges he is facing, in order to match exactly his skills with the requirements for action.
2. It should be easy to isolate the activity, at least at the perceptual level, from other

stimuli, external or internal, which might interfere with involvement in it.

3. There should be clear criteria for performance; one should be able to evaluate how well or how poorly one is doing at any time.

4. The activity should provide concrete feedback to the actor, so that he can tell how well he is meeting the criteria of performance.

5. The activity ought to have a broad range of challenges, and possibly several qualitatively different ranges of challenge, so that the actor may obtain increasingly complex information about different aspects of himself. (CSIKS 79, p. 213)

The following sections will describe Malone's three motivators—challenge, fantasy and curiosity—in more detail.

1. Challenge

The element of challenge has four components: goals, uncertainty, toys versus tools, and self-esteem. Malone's research determined that goals are the single most determinant feature for game preference. A good goal must first be personally meaningful. The users need performance feedback to let them know if they are achieving their goal. The goal can be predetermined such as in the game *PacMan*™ by Midway Manufacturing Company, where the player's character eats dots and scores points. Alternately, the goal can emerge from the interaction between the user and the game such as in the drawing program *Kidpix*™ by Broderbund Software, Inc., where the user draws a free-form picture. (MALON 84, pp. 85-95)

The uncertainty of achieving a goal is an essential element of challenge. Uncertainty as to whether or not the user will reach the goal provides another form of challenge. There are four different sources of uncertainty - variable difficulty level, multiple-level goals, hidden information, and randomness. The difficulty level can be selected by the user, selected by the computer (based on the user's skill), or determined by the opponent's skill (chess). There are two kinds of multiple-level goals. The goals may all be the same type but have different degrees of difficulty. This provides a variable difficulty level within a fixed problem environment—the same game. Alternately, there are high-level goals which require accomplishing a series of lower-level goals. This usually involves

solving problems faster or with fewer steps. The high-level goals are generally applicable to instructional games where the user wants to maximize previously-learned information. Hiding information provokes curiosity while invoking an additional challenge to the user. Hidden information adds to the uncertainty of a game. Randomness adds to the uncertainty of the outcome because the user cannot accurately predict results.

If users often succeed in a challenging activity, their self-esteem generally improves. However, if students continuously fail at the challenging activity, self-esteem can decrease. This implies that instructional activities should have varying degrees of difficulty so that students can work at the appropriate level at that time. Feedback should be presented in a format and quantity that minimizes damage to the user's self-esteem, while maintaining the quality and usefulness of the feedback.

2. Fantasy

Fantasy is the second component used to make a game interesting. Fantasy is a natural element of all children's play. Children create make-believe characters that they use to help understand their daily experiences. The fantasies allow the children to deal with new or uncertain events at their own pace, without any threat from the unknowns of reality. Fantasy characters have been used by cartoon creators because they have a great appeal to children. Incorporating this element into the education process will help make learning more interesting, exciting and even more transparent to children.

Malone defines "a fantasy-inducing environment as one that evokes mental images of things not present to the senses or within the actual experience of the person involved" (MALON 84, p. 87). It is a creation of the imagination. He continues to explain that the fantasy objects can be physical, such as balls, or situational, such as being a super hero. These fantasy objects may or may not normally occur in the person's environment.

Fantasies are creations of the imagination. Fantasies can be extrinsic or intrinsic. Extrinsic fantasies depend on the use of skill alone such as addition or reading to reach a fantasy goal such as scoring a run in baseball or not getting hung in hangman. Speed of

answering can be a factor in extrinsic fantasies such as in a speedway game. The type of problem used can vary because the problem does not depend on the fantasy in any way. Using a math problem or a spelling problem does not affect the extrinsic fantasy. On the other hand, intrinsic fantasies depend on the skill, and the skill depends on the fantasy. Problems for this type of fantasy usually relate more closely to the fantasy, and the feedback received is a more natural part of the fantasy. An example of this is the game *Treasure Mountain*™ by The Learning Company, where reading is required to progress up the mountain. The reading directly relates to the scenario. Of the two types of fantasies, intrinsic fantasies tend to be more interesting and more instructional. Intrinsic fantasies also provide some guidance as to how to use the problems in the real world, whereas extrinsic fantasies do not. Also, the cognitive advantages of fantasies (next section) apply only to intrinsic fantasies.

Intrinsic fantasies often help the user apply old knowledge to new problems. They help them apply known information or a known way of thinking to a new scenario to come up with new information. Also, the fantasies usually provoke detailed images related to the information. The images help the user remember the information.

A person's emotions play an important part in the appeal of a fantasy. Since each person's emotions are unique, each person will find different fantasies appealing. Good games should then be constructed that allow the user to select the fantasy (with the same problems as a different fantasy) or even create their own fantasy (they could create the characters...). This is a major attraction of the game *Dungeons and Dragons*™. This freedom of choice is itself an important motivator. While providing flexibility in fantasy choices, it is important to ensure the users don't learn from playing the game that aggressive fantasies solve problems. This may help make them more aggressive in real life.

3. Curiosity

Curiosity is a very important element of motivation. When an individual's curiosity is aroused, their interest and motivation increase. Concepts such as novelty,

complexity, surprise and incongruity are all sources for arousing one's curiosity (MALON 84, p. 71).

The user's curiosity can best be aroused if the game's environment is at a level appropriate for that user. The environment should not be too complex or too simple for the user's current knowledge level. The environment should be novel and surprising (provide surprising feedback so it doesn't become too predictable and routine) but not too ridiculous. In general, the user will know enough to have expectations about what will happen, but some of his expectations will not be met and things he did not expect will surprise him. To nurture challenge and curiosity requires adjusting the environment to the user's level and providing feedback.

Sensory curiosity is aroused when there is a change in sensory stimuli of the environment (sound, light...). Computers are great tools to arouse sensory curiosity through graphics, animation and music. These elements can be used as decoration, to enhance fantasy, as a reward, and as a display system to show the user what is happening. It is much easier to see what is happening via pictures and sounds than through text alone.

Cognitive curiosity is aroused when a user realizes he hasn't completed the task. By providing just enough information to the user to make their existing knowledge seem incomplete or inconsistent, the learner becomes motivated to learn more "to complete the picture." Frustration needs to be prevented here by making the gap between what the user knows and what he doesn't know just big enough to arouse his curiosity, but not big enough to cause frustration. This information can be given as constructive feedback so the user not only finds out their answer is incorrect, but they are given information that helps them figure out the correct answer.

B. LEARNING

Once we have motivated an individual, real learning can take place. With a motivated learner, we need to ensure we have provided a positive learning environment to make the

most of the learning process. Some of the items needed to make a positive learning environment include:

1. A positive attitude by the teacher: Once a child is labeled and put in a special class, a negative stigma is frequently applied to the child. The child is not expected to do well and is constantly told, either directly or indirectly, that they can't learn. The child begins to believe that he can't learn, and therefore doesn't learn.

   The teacher must be patient and positive to help the child believe in himself and eventually the child will learn. The method presented may have to be modified so the child is interested, but it is very important to maintain a positive attitude. A well programmed computer system can be as patient as the student needs. It will not become exasperated or cross.

2. A fun environment: Most children put in a special class get remediation in the same things they didn't do well in regular classes, the same routine, maybe even cryptic, worksheets. Generally, the child has already demonstrated that he doesn't like them and doesn't do well with them. This makes the environment miserable for the child. Many children only need a different way to learn the same concept. Instead of worksheets, the child may need a musical game to help them understand the information in a way that has meaning to him.

3. An interesting subject: It is very difficult to learn something that does not have any meaning or relevance to the learner. To make learning exciting and interesting the material needs to be presented in a way that means something to the learner. Instead of having a child learn to read using a subject such as wiring a light switch, it would be much more appropriate to have a story about a child's first visit to a farm. That is a subject that the child can more easily relate to and derive personal meaning from. "In *On Learning to Read* Bettleheim and Zelan show very clearly that in reading as in everything else, children seek out meaning, which is to say, whatever helps them make the most sense of the world we live in (HOLT 1983, p. 147)."

   If the program incorporates reading skills as steps to completing the game instead of steps in learning to read, then the student is more likely to remain interested. Adding good graphics and sound effects to a meaningful story adds to the interest of the subject for the child and thus increases their desire to learn.

Variety is also important for maintaining the student's interest. Instead of constantly using the same types of stories, they can be altered to provide variety. Varying the story type from biography to adventure to history will show young students that there is a story type for all readers. When a student is using a story that he is interested in, he will work harder to solve the puzzle of letters, words and sentences. The power of the program described in this thesis is in the ability of the teaching expert module to vary the presentations to maintain a high level of interest.

Now with a motivated learner who is presented with some material that is meaningful, effective learning can take place. "Learning" is defined in the Merriam-Webster Dictionary as gaining "knowledge, understanding or skill by study or experience" (MERRI 74, p. 401). A skill is your level of proficiency on a specific task while ability is the measure of your capability to do something. So, any given student currently has certain abilities to work with. Through study or experience, the student can acquire skills. While acquiring skills, his ability level increases. As stated by Petho, "The blend of abilities that support performance on a task changes as practice continues and proficiency increases (PETHO 92)." The goal is to build the base level of knowledge that a student already possesses by gradually increasing the number of and levels of skills he has.

Bower developed seven rules (BOWER 81) to enhance skills acquisition that will be incorporated into the computer assisted instruction program described in this thesis. They are:

1. Distributed practice works better than massed practice. This means that a skill is acquired more easily using many short practice sessions spaced widely apart rather than long practice sessions held close together (cramming).

2. Imitating actions of experts cuts training time. In this case, reading to a child gives them an example to learn from—to imitate. The child can begin to understand the vocabulary, how the different words are used together, and how different intonations are used. A child will not learn to read if he does not see that the printed words on a page really tell a story. Until he sees that by being read to, and begins to make sense of the words, he will not learn. The example by the expert (parent, teacher, or computer) is very important in helping solve the puzzle of learning (to read) and decreasing the learning time required.

3. Doing the task rather than watching and listening to someone talk about it helps learning. Once the child begins to understand the skill to be acquired, it is essential he perform the task himself to help him learn by doing. It is much more difficult, if not impossible, to learn a new skill without doing it. A person can listen to an expert describe how to ride a bike and watch them demonstrate for a month, but until he actually hops on and tries for himself, he will not, in most cases, be able to ride the bike. An individual must personally learn the "feel" of riding a bike—how to balance it and how to shift his weight when turning or pedaling. Until an individual actually tries a new task, it is almost impossible to acquire it as a skill.

4. Immediate and true feedback is critical. If a person does something and is immediately told whether it is right or wrong, he can immediately make the necessary adjustments to increase his learning. If he is wrong, he tries to figure out

why and adjusts what did as necessary. If he was right, his actions were reinforced as being right and then he uses that "new skill" to learn the next step.

If feedback is not given immediately, the user does not know whether he is correct or incorrect. As a result, he could be learning to do something incorrectly and then when he finally finds out he was wrong, he must unlearn it. This is a very difficult task. "The hardest problem for the brain is not learning, but forgetting. No matter how hard we try, we can't deliberately forget something we have learned (SMITH 86, p. 47)." Another powerful feature of CAPER is that it will provide feedback in seconds instead of days. It can also selectively reinforce weak skills on an individual basis.

5. Break the task up into parts (divide and conquer). Learn the hard parts separately. Piece them back into the whole task later. Trying to learn something difficult can be overwhelming. Often, it is impossible to learn the whole task all at once. It is better to break the task down into smaller, manageable pieces and gradually fit the pieces together to form a whole. For example, in trying to learn how to do a lay-up in basketball a person needs to learn to dribble the ball while standing still, dribble the ball while running, jumping off one foot, and shoot the ball with one hand. Trying to master all of these at one time is very difficult. But if he takes them one at a time, and then he takes two skills and combine them together, and then three skills, he'll eventually be able to do a lay-up. The same concept can be applied to learning any task that can be broken down into smaller, more manageable pieces.

6. The more important a task is to the learner, the faster it will be learned and the longer it will persist. If a teacher takes a young boy and tries to get him to learn both multiplication tables and baseball on the same day, more than likely he will learn the game of baseball more easily than the multiplication tables. His friends probably play baseball, he watches it on television, his dad and mom probably tell him stories about when they were young and played baseball. The game becomes a positive part of his life and he is a motivated learner.

   On the other hand, his friends probably don't sit around after school practicing their multiplication tables. He doesn't watch television shows on the multiplication tables and his parents more than likely don't tell exciting stories about the multiplication tables like they do about baseball. Multiplication tables are not glamorized, really have no meaning to him because he doesn't understand why he has to learn them and he doesn't see how they affect his daily life. The child will gladly put effort into baseball while learning multiplication tables becomes a chore he has to do only because the teacher said so. If personal meaning can be applied to a new skill to learn, the child will want to learn it and will actively work at mastering the new skill.

7. More distinctive parts of the task will be learned faster than less distinct parts. In the previous example an individual would find shooting the basketball easier to learn than the preliminary part of the lay-up. Shooting the ball is one action that is easily understood by itself. Whereas the separate tasks of dribbling, running, and transferring the ball are combined to make a layup; making the layup is harder to understand and do. The more identifiable and independent a task is the faster it will be learned.

Some other concepts that are important to learning include (PETHO 92):

1. Positive and negative transfer of training.

Positive transfer occurs when learning one task facilitates learning another. This could be termed the building block approach. When a child is learning to talk, they first learn some individual words. Once they have learned some words, they can begin to form sentences. They do not form sentences before they have learned words.

Negative transfer occurs if how the first task was learned interferes with learning the second. This occurs when the first task is not fully learned. It can cause confusion in learning the second task or the person may just not have enough knowledge to learn the second if the first isn't mastered.

When the first task is partially learned, negative transfer occurs, but when the task is overlearned (there is no change in performance with more training), positive transfer occurs.

2. The Magic Number Seven

Humans can remember five to seven items of information at one time (MILLE 76, pp. 81-97). Since only 5-7 items can be remembered in short-term memory at one time, it is counterproductive to try to cram more in. This reinforces Rule 1, which says distributed practice works better than massed practice.

Memory is a key aspect of learning. There are four central elements of memory: Sensory storage (sometimes referred to as immediate memory), short-term memory, long term memory and retrieval (PETHO 92).

Sensory storage is the first step in information acquisition. It works at the sensory level and lasts less than one second. It is the visual and auditory aspects of seeing something. This information is encoded and passed to short-term memory.

Short-term memory works with the visual, phonetic and semantic aspects of information. Short-term memory can handle five to seven pieces of information at one time and lasts about 18 seconds. If the information is rehearsed during this 18 seconds the information may be transferred to long-term memory.

The modern view of long-term memory is that it is an active process of recreating, not just recovering, past events and information (PETHO 92). The information is stored according to its meaning (semantic coding). This type of storage allows many people to remember the gist of an idea without the details. If the information is organized in a meaningful way when it is presented to an individual, it will be easier for the individual to retrieve it.

Retrieval requires reasoning and memory. We remember some things and then use our reasoning to helps us remember more. For example, if a person wants to remember what direction the bedroom window faced in the house he lived in ten years ago, it wouldn't necessarily be important to remember that fact (it may not have ever known), but by remembering other pieces of related information such as streets in the area and which direction they ran, where the sun rose and set, which side of the house had shadows in the morning or evening... he can derive which direction his bedroom window faced.

The two basic methods of retrieval are recognition and recall (PSYCH 72, p. 737). When an individual is presented with some information and asked whether he has seen or heard it before, he is being asked if he recognizes it. This type of memory is what is used on multiple choice tests and is easier than recall. Recall is using clues to identify the appropriate memory to be retrieved. There is a third process, that is sometimes confused with retrieval, called confabulation. Confabulation is the process of using imagination and reasoning skills to create an appropriate response. Items created through confabulation are not necessarily accurate, but may be based upon some accurate information (PETHO 92).

C. THEORY OF MULTIPLE INTELLIGENCES

With an understanding of what is needed to motivate a child and a glimpse at a few of the main concepts that help us understand learning, the next step is to define a way of teaching children.

There are many theories defining the "best methods" for teaching all children. Many of them dictate one specific method that all children will learn by. The problem with many of these theories is that they assume all children learn the same way. Gardner says this "is defensible because certain features do characterize the learning of all students, or at least the vast majority (GARDN 91, p. 11)." He identifies seven human intelligences and we all use them to varying degrees to learn, represent and utilize knowledge (GARDN 91, p. 12).

The seven intelligences that Gardner says all people possess and use to varying degrees are linguistic, logical-mathematical, spatial, musical, bodily-kinesthetic,

interpersonal, and intrapersonal (GARDN 91, p. 15). Each of these intelligences is explained below and summarized in a chart in appendix A.

Children with a high level of linguistic intelligence "have highly developed auditory skills and enjoy playing around with the sounds of language (ARMST 87, p. 19)." They like to read, tell stories, do word games or just talk. They learn best by saying or hearing and seeing words.

Children gifted in logical-mathematical intelligence think conceptually. They like to work with things in a controlled and orderly way. They like, and do well at, things that require reasoning ability such as chess, checkers, brain-teasers, logic problems, and computers.

Children with a high degree of spatial intelligence "think in images and pictures (ARMST 87, p. 21)." They like art activities, are good with maps, enjoy jigsaw puzzles and mazes, designing/inventing things, building with lego blocks, and have a tendency to daydream a lot.

Musically-gifted children are generally found singing, humming or whistling, often when they're supposed to be doing something else. They start "dancing", moving around when music is on or even to their own singing. They tend to be rhythmic, hear sounds of nature more than others, have an "ear for music," and may play an instrument. Some musically inclined children just appreciate listening to music.

Bodily-kinesthetic children "process knowledge through bodily sensations (ARMST 87, p. 22)." They seem to be constantly in motion. Some tend to be athletically inclined (gross motor skills) while others tend to be better at fine motor coordination skills demonstrated through such activities as drawing, crafts, or fixing things. These children learn by moving and acting things out, and are constantly moving around in their chairs at school. If not given an opportunity to learn physically and release their energy, they can very quickly be labeled hyperactive.

Interpersonal children "understand people" (ARMST 87, p 23). They are the "born leaders" who always seem to be organizing groups of people or mediating conflicts

between peers or family members. They tend to socialize and seem to know how people feel.

Intrapersonal children "possess strong personalities (ARMST 87, p. 24)." They tend to be independent and sometimes shy, living in their own, personal world. They are generally self-motivators who work independently to complete projects and are not very concerned with what others think of them (their style of dress, behavior, or general attitude) because they have a deep sense of self that guides their actions.

Everyone possesses each of these intelligences to varying degrees. As a result, everyone has a unique style of learning that best parallels their array of multiple intelligences. To maximize learning, it is important to expand beyond the two-intelligence (linguistic, logical-mathematical) scenario and develop methods to teach children so that they can learn, regardless of their learning style (ARMST87, p. 40) (GARDN93, p. xv).

"The broad spectrum of students—and perhaps the society as a whole—would be better served if disciplines could be presented in a number of ways and learning could be assessed through a variety of means (GARDN 91, p. 12)." Thomas Armstrong said that "schools fail our children when they limit their teaching methods to lectures, textbooks, worksheets, and quizzes. They create learning problems when they focus on a narrow band of isolated skills representing only two of Howard Gardner's seven intelligence (ARMST 87, p.40)."

To illustrate an important point, one student, Tom, may have highly developed linguistic and logical-mathematical intelligences which allows him to perform well in school and on tests. At the same time, Tom is not very well developed in spatial and musical intelligences, so he does poorly in music and the arts. Another individual, Joe, could have strong musical and spatial intelligences but weak linguistic and logical-mathematical intelligences. He will do well in music and the arts, but poorly in reading, writing and math and poorly on tests. As a result, Joe gets additional tests to determine why he doesn't do well in school, does poorly on tests, and may be labeled "learning-disabled". At this point, much emphasis is placed on Joe's problem and his strengths are virtually forgotten about.

He has demonstrated an inability to do well in our traditional schools and thus must receive remedial traditional instruction. To accomplish this, Joe is usually placed in a separate class and indirectly (and sometimes directly) told he is dumb. His old classmates start calling him names and he soon begins to believe that he has a learning problem. Joe's only real problem is that he learns differently than our schools teach.

Thomas Armstrong gives the example of a child named Billy who doesn't fit into the mold defined by our schools:

> Billy loved to invent crazy machines. One of them caused water to run down a chute, moving ping-pong balls into sockets, in turn causing bells to ring and a miniature pig to spin around. This finally moved an alligator's head into which you could stick your pencil to be sharpened. Other machines did similarly creative and practical things. Yet in spite of these innovative projects, Billy was flunking out of school. He couldn't seem to do things the school's way. For example, when Billy's mother asked him to figure out the area of a room using the methods the school had taught him, Billy struggled. He tensed up his body, erased frequently, and finally came up with a totally unrealistic answer.
>
> Then Billy did it his way. "Billy shut his eyes and made little rhythmic movements with his head, as if he were listening to an inner song. After a while he jotted down something on the pad, closed his eyes for some more internal business, opened them, jotted something else down, and gave us the correct answer." Asked to describe the process, Billy responded, "Well, when I close my eyes to figure something out it's like a cross between music and architecture." (ARMST 87, p. 1)

Billy could easily be labeled as learning-disabled and be condemned to the world of special education. He could also be lucky enough to have someone realize that he isn't learning-disabled—he just has his own unique learning style that doesn't fit in traditional American schools. If effort is taken to teach to his unique style, Billy can not only learn the material his peers are learning, but he will probably also develop his weaker intelligences through the use of his stronger intelligences.

As stated in Chapter One, this paper supports Gardner's theory that all children are gifted to varying degrees with each of the seven intelligences. Ross (ROSS 77, p. 123) supports this concept, and states that children need specialized training to support their learning style. It is possible to identify a child's learning style, their dominant intelligences, with a computer system. This information can then be used to teach the child in a way that

uses their strong intelligences. If done correctly, it will not only help them learn the subject at hand, it will also help strengthen their weaker intelligences.

This chapter has discussed the learning process and briefly explored Howard Gardner's Theory of Multiple Intelligences. The next chapter will look at how to adapt the learning process to different learning styles - how to effectively teach using the Theory of Multiple Intelligences. In subsequent chapters, the theory is blended into an ICAL system which allows program personalization through CAPER.

III. TEACHING TO VARYING LEARNING STYLES

Since children all learn in different ways, it is important that the tools and teaching structure are developed in ways that provide all children an opportunity to learn, not just those strong in linguistic and logical-mathematical intelligences. To do this, teaching methods need to be evaluated to determine how to adapt lesson plans to meet the requirements of the seven different intelligences.

A. THE APPROACH TO TEACHING

When developing a lesson plan to teach a subject to students, all seven intelligences should be used. Currently, most teachers use only the linguistic and logical-mathematical intelligences. Employing the other five intelligences would insure that all students have a good chance to learn. Even though this approach may require more preparation time, it will pay huge dividends in several ways. First, the students that are less linguistic and logical-mathematical will also have their needs met, so they will be less disruptive. Second, because all students learn with all seven intelligences, albeit to different degrees, then it can be argued that all children will learn faster and with less repetition when the maximum number of intelligences are employed for each learning task. Just as important, stimulating all students to use all seven intelligences will cause each student to develop all their abilities.

To start looking at how to develop these enhanced lesson plans, it is important to understand what types of questions can be used to engage each intelligence in a manner that supports the instructional objective. Some examples presented by Armstrong are listed below [ARMST 93]:

Linguistic: How can I use the spoken or written word? How can I use storytelling?

Logical-Mathematical: How can I bring in numbers, calculations, logic, or critical thinking skills?

Spatial: How can I use visual aids, visualization, and/or color?

Bodily-Kinesthetic: How can I involve body movement, or the use of hands-on experiences?

Musical: How can I bring in music or environmental sounds, or set information in a rhythmic or melodic framework?

Interpersonal: How can I engage students in dyads or small groups?

Intrapersonal: How can I evoke personal feelings or memories, or give students choices?

Using these questions will help teachers begin developing classes around the seven intelligences theory. By adding a little creativity and the suggestions of others, the classroom can become a dynamic, fun-filled learning environment where real learning takes place for all students.

B. A SAMPLE LESSON PLAN FOR ALL SEVEN INTELLIGENCES

In a school environment, there is a good chance that there are children strong in each of the seven intelligences in a classroom. To ensure that all those children are given an equal opportunity to learn to read using their strengths, it's important to incorporate each of the seven intelligences into the lesson plan.

Below is an explanation of how reading can be taught to all seven types of intelligences. It is important to keep in mind that, in most children, two or three of the intelligences are dominant. The children learn faster when the teaching methods match the dominant intelligences, but if all their intelligences are challenged, they may learn best when applying what they have learned with their strong intelligences to their weaker intelligences.

Linguistically—There are two sub-classes of linguistic children, those that love to tell stories and those that can easily hear the different sounds that make up a word. The second group would learn very easily using the traditional phonics methods. However, it's important to ensure the material is presented in a way that is fun and challenging for the

child to prevent boredom. The linguistic children love to hear themselves talk and love to hear the stories they've created. Making a book based on what the child narrates is a good way to help this child learn. The teacher can either write or type (large print preferred) the story, and have the child add illustrations and then read the story back. Associations between what is said and what is written will begin. The words and ideas on the paper are his, therefore it has more meaning. The story can also be taped with a tape recorder which will allow playback as often as requested. Again, this will help the child learn the association between the written and spoken word.

These two children use two fundamentally different learning styles. The auditory child is better suited for a phonics approach, while the storyteller will learn better using a whole-language approach. Again, it is important to emphasize that no one method is equally beneficial to all students. Teaching in a way that every child's dominant intelligences are used produces the most learning in the least amount of time.

Spatially - Children that learn spatially tend to make great use of their imaginations, and are often caught daydreaming. Part of using their imagination is creating vivid pictures of their ideas. A rebus[1] can be used to help a spatially intelligent child to read. Having the picture and word together, or alternating between the two when the story is read, will help this child learn to make the association between the written word and the picture. A twist to this approach is to make pictures using the different letters or words. It is very easy to make a snake look like the letter 'S'. With a little imagination it is possible to take a word such as HOME and add drawings to it so it looks like a home (Figure 1).

1. A rebus is a pictorial representation of a word or syllable.

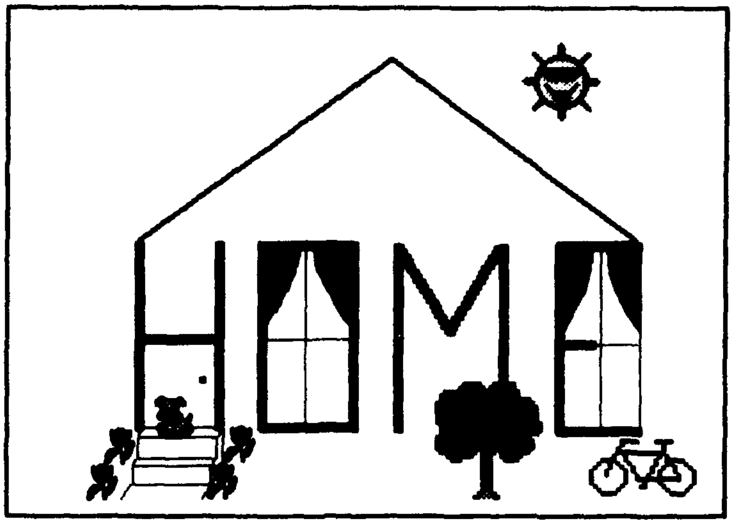


Figure 1: A pictorial representation

Rebuses and pictorial representations can do wonders to help a spatially strong student learn how to read because they have a way to visualize the word. Other similar methods can be created with a little imagination.

Kinesthetically - These children need to use their body to learn. Many of these children get labeled as hyperactive because they can't sit still in a classroom. Constantly fidgeting and moving is just their way of learning. Preventing them from moving around, either through constant discipline or with drugs, can stifle their ability to learn. Kinesthetic children need to use their bodies to learn. It is important to allow them to draw and do hands-on activities before they are involved in more structured methods of learning to read.

Kinesthetic children want to use physical objects to "build" sentences. These objects can be blocks, sand, paint, etc. Allowing them to create or manipulate the words will provide a greater opportunity to use their strengths to learn how to read. Using a computer is another good tool because the children are physically creating the words. Some of these children will even need to stand at the computer instead of sit, so they can continue to move around. If they can't wiggle, their brains cannot be fully engaged.

Two other methods that can be used to help the kinesthetically-intelligent child learn to read are the use of Braille or sign language. Both of these require the more keenly developed sense of touch that many kinesthetically-smart children possess. Both Braille and sign language can be used in conjunction with normal text similar to rebuses. Some "dyslexics" have discovered how to read using this method [ARMST 87, p. 82].

Musically - These children learn to read best when their reading material is sung to familiar melodies. By either applying the story to a song or buying a prerecorded story, the child will be drawn into the story through their musical intelligence. It is necessary to provide the words, in large print, so that the children can follow along and begin to connect the words to the song. Eventually, musically-intelligent children will make the connection, begin to break the reading code, and begin to read.

Logically-mathematically - These children love patterns. Logical-mathematical children like rhyming readings, such as Seuss' *Hop on Pop*. The book is packed full of simple rhyming words such as "UP PUP Pup is up. CUP PUP Pup in cup. PUP CUP Cup *on pup*." (SEUSS 63, pp. 3 - 5) The logical- mathematical child will begin to see the pattern in these words. This book also makes lists of the separate rhyming words in the cover pages of the book. Using these lists or creating similar ones helps this child learn the pattern of creating new words, simply by replacing the beginning sound. Games can be played using blocks or magnetic letters to see how many words can be created by replacing only the beginning sound. Some computer games also incorporate this technique, such as The Learning Company's *Reader Rabbit® 1*.

Interpersonal - These children love to be read to, and may enjoy reading to others. It is important to read out loud with them or have them read with siblings or friends. Having interpersonal children read their own parts of a simple play provides them with an opportunity to read as well as to share with others.

Intrapersonal - These children love to read by themselves. Intrapersonal children need a quiet place away from others to enjoy a high-interest story. With some guidance and having someone available to answer questions, these children can teach themselves to read.

However, intrapersonal children can also be discouraged from reading by high-pressure reading in school. They can easily become a learning-disability statistic if they don't have the quiet time they need to turn-on to reading.

It is very important to expose all children to the learning-style that best suits them when it comes to reading. Thomas Armstrong says it well [ARMST 87]:

> Exposing children to a "brain-compatible" reading approach may be one of the best things you can give them academically. When they experience the pleasure that comes with success during the first stages of learning to read, they gain positive associations to academic learning that they carry with them for the rest of their lives.

C. SUMMARY

This chapter has examined ways that Gardner's Theory of Multiple (Seven) Intelligences can be used to teach all children, not just those labeled "learning-disabled," in a much richer and fuller manner. The chapter has also briefly looked at an application of this technique for children who are learning to read. Introductory questions were provided with examples of implementation for reading. The next chapter will concentrate on applying this theory in Intelligent Computer-Assisted Learning (ICAL).

IV. INTELLIGENT COMPUTER-ASSISTED LEARNING

A computer, programmed and used properly, can be a great asset to both the teacher and the student. Computers have the potential to greatly enhance the material taught by teachers, while at the same time providing a one-on-one, non-threatening environment for students to learn. This aspect alone is very helpful for "learning-disabled" children and their teachers. An Intelligent Computer-Assisted Learning (ICAL) program can take the time to repeat a lesson over and over without feeling the pressure of the demands of the other students in the class.

There are many opinions concerning the use of computers to help children learn (CRAWF 81, p. 1) (LESGO2 83, p. 31) (BRAND 87, pp. 118-130). Many people who are concerned with the computer's use are afraid that it will become the primary method of instruction. It is important to realize that the computer must be used with other, more traditional methods of instruction and is only one part of a well-rounded and exciting learning opportunity. The teacher must still be the dominant teaching force in the classroom. As Alan Lesgold notes, "A computer cannot replace human role models in education, nor is it smart enough to supplant human teachers in their sympathetic interaction with children (LESGO2 83, p. 30)." When used properly, computers can have a very positive effect on the teaching and learning processes.

This chapter will discuss some of the advantages and disadvantages of using computers for teaching children, the characteristics of a good program, and briefly evaluate some programs that are currently used.

A. ADVANTAGES OF USING COMPUTERS FOR TEACHING AND LEARNING

1. ICAL Systems can Involve Multiple Senses

A computer can provide a multi-sensory learning environment for the student. Most computers in use today are capable of stimulating the senses of seeing, hearing, and touching. The student sees what is displayed on the screen, hears the sounds reproduced by the speaker, and touches the mouse, the keyboard, and, on some computers, the touchscreen.

Sound is often used in the classroom to enhance the learning process. Children with powerful musical intelligences can be kept focused on the lesson with use of rhythmic sounds. It is relatively easy to add basic sounds to a program on most computer systems. Different sounds can be used to help the student remember sequence, or just help keep the other intelligences focused on the lesson long enough to master the material. If a stereophonic system is used, the spatial intelligence can be involved.

Sound can help the child with a strong linguistic intelligence who can not yet read. The linguistic person loves stories and playing word games. They may become very frustrated if they can not read. The computer can "read" stories and play word games using voice synthesis. For example, if a child is to match one of three lower case letters to a displayed uppercase letter, he will remember each displayed letter more easily if it is visually highlighted in some way and it is verbalized by the system.

The final sense used when interacting with computers is touch. Touch is generally not used as much as seeing and hearing. In addition to touching the keyboard or a mouse for input, a touchscreen can be used. A touchscreen, as the name implies, allows a user to make choices by reaching out and actually touching the screen. If, for example, the child has to touch the lower case letter that matches the uppercase letter "B", he will be seeing the letter, hearing it pronounced and touching the area of the screen where the letter is. When a child with strong spatial intelligence tries to remember the shape of a lower case

"b" he will have a better chance of choosing the "b" instead of a "d" because he can feel, or remember a spatial difference between the "b" and the "d" on the screen. He may also hear it being said in his mind. With multiple senses being used, the chances of the student correctly remembering the information is increased.

2. ICAL Systems can be Highly Adapted to Individual Students

One of the key advantages of using a computer to present instructional material is the ease of varying the visual presentation. All children are not equally stimulated by any one graphic image or theme. The computer program can be designed to present the same lesson in several different ways and automatically select the screens that are most likely to capture the attention of the student. For instance, a student that has trouble reading will not be attracted to a screen filled with text, but a highly graphic screen with simple instructions may keep his attention long enough for him to read and follow the instructions. Thus, he will have a confidence building success instead of being intimidated. On the other end of the scale, this highly graphic screen may be overwhelming for a child that has trouble focusing. This person may well respond better to a simple, soothing screen with very little information to process, and straight-forward choices. An interpersonal child will probably respond well to some kind of character that acts as a guide or mentor, while an intrapersonal child is more likely to think that the character is a silly affectation and quickly become bored with the program. A well-written program can determine the students' preferences, based on how they react to sample choices in a front-end diagnostic test, that may be disguised as a short game, and present them with screens that are optimized for that individual's dominant intelligences and learning styles.

Providing information in a multi-intelligence format increases the chances one of them will be a strong intelligence for the user. This is of particular importance for the "learning-disabled" child whose learning "disability" is having dominant intelligences other than linguistic or mathematical/logical. As an added benefit, the brain will process the information in two or more different ways, increasing the number of neural paths that are

developed which in turn, increases the chances that it will be remembered. Every additional facet of the students intelligences that can be employed increases the attention that the student will focus on learning the assigned task, since it is harder to ignore stimuli that engage multiple senses.

With effective programming employing recent developments in object oriented programing and expert system engines, a powerful program can be written that is self-tailoring. The expert system will diagnose both the student's ability and learning preferences. From the learning preferences, the expert system will deduce the dominant intelligences and select lessons and styles to most effectively present the material to the student. The inheritance characteristic of object-oriented programming and the ability of the program to build links and calls on the fly greatly reduce the programming efforts and allow for the vast number of dynamic changes that are necessary to take advantage of both the gross and subtle differences between learning styles.

A less powerful program requires the teacher or the student to set default settings and to modify the program as the student accomplishes the tasks. This will be easy to do using menus and help screens. In between these two extremes are many possible approaches that may use techniques such as strings of "if then" statements to automatically increase the difficulty as the student's performance improves.

While it is true that a computer system is limited by its hardware and programs, the fact is that it can be very versatile. A good, intermediate program can be tailored to the needs and abilities of the individual student. This can be done most easily by setting defaults for the user that are used each time the program is used. The program can have many ways of presenting the lesson, selected by the student or teacher through software switches. The defaults can be set by selecting choices from a menu. This menu can be locked, or invisible to the user. More advanced students may use a program with pull down menus which change the difficulty level or even which intelligences the program addresses.

CAPER, an objective system, is self-adapting and uses a series of interview techniques, camouflaged as a game, to determine the students dominant intelligences.

Based on the results, it builds a lesson plan to teach the material in a style that makes it easier for the student to learn and strengthen the weaker intelligences at the same time. The methods used and the difficulty of the tasks are adjusted constantly, based on how the student responds during the lessons and tests, reinforcing the student's successes. These adjustments are gradual and transparent to the user, except in those cases where the program determines the need for a graduation, or promotion-type change. This program, or collection of programs, is capable of presenting the lessons in many different formats ranging form very simple textual messages to high energy multimedia productions. The only deciding factor being what works best for the particular student logged on at that time.

CAPER uses an expert system to provide the evaluation and decision-making capabilities, and object-oriented programing to provide the many different dynamic cross links that are needed to present the lessons in so many different ways and to be able to modify itself while it's running.

An example of this could be determining what type of math problems to give to a student. The expert system evaluates how well the student is doing and possibly how fast he is solving the problems to determine the appropriate level and mix of problems. It is not limited to simple addition. The program changes the problems as the user's needs dictate. It could presents the problems in a variety of ways to determine how the student prefers to do the problems. One method may be worksheet style (2 + 3 = ___) for the mathematical-logical children, or moving groups of objects around for the bodily-kinesthetic child, or doing problems to music for the musical child, or a word-problem format for the linguistic child. The program uses combinations of different methods to help strengthen the weaker skills of the child.

3. ICAL Systems can be Patient Tutors

One of the biggest advantages to using a computer is that it has the capacity for great patience. It can allow the student to repeat the same task over and over without getting upset, bored or distracted. A student can repeat the same thing until he understands it or gets

tired of it. The computer will give consistent responses. It will not snap at the user because the "teacher" is having a bad day. It may not count the number of times the user did the same problem. A properly-programmed computer can be infinitely patient and consistent when it is appropriate. The value of this to a slow learner cannot be over emphasized.

Many children, especially those who are not linguistically oriented or who are intrapersonal, do not like being called on by the teacher. They freeze up and can't think because of the intense pressure they feel. As a result, they often fail to answer the teacher's question and are more tense the next time they are called on. It becomes a never-win situation for the student. Many of these children love using a computer. They do not feel the pressure to answer and provide the correct answer. They do not have the intense fear of failure that they feel in an open classroom. They are one-on-one with the computer and feel more relaxed, and are thus more able to learn. The computer, when properly programmed, will provide positive feedback. Using a computer thus helps give non-linguistic and intrapersonal students a chance to maximize their potential in a way they are comfortable with. As a result, their self-confidence grows and they are better able to interact with the class. With their growing self-confidence, they can learn to translate the information they learned on the computer to the open classroom and begin to overcome their fear of failure.

A computer can provide immediate, positive feedback. Studies have shown that feedback enhances learning. They also show that it is important for the feedback to be given immediately with an explanation if necessary, instead of just the correct answer. (CRAWF 81, p. 12) The feedback can be more consistent, more often, and more repetitive, if necessary, than that provided by a teacher. A teacher generally has 20 - 30 students to respond to, and physically can't provide the one-on-one feedback a computer can. There are times when this immediate feedback is essential for learning. Because the computer's responses are immediate, the chances of increasing learning is greater than when a student gets back a corrected worksheet (some children even look at the corrections) several days after they did the work. A child who is learning a new word may need to hear it over and over. Using a program such as *Kidworks*™ 2 by Davidson & Associates, Inc. (KIDWO 92),

the child can have the computer say it to them as many times as necessary. The child knows he has to hear it over and over. The computer can satisfy that need. In most cases, the teacher won't be able to.

A computer doesn't give unintended negative feedback either directly or indirectly (if programmed properly) like teachers frequently do with comments such as, "that's incorrect" and their nonverbal signals. A fellow classmate or teacher may roll their eyes, sigh or just have a look of disappointment on their face when Johnny misses the same word for the fifth time. A computer can give the same response the fifth or even 100th time as it did the first time. There won't be any negative human emotion added because of the number of times the word was missed. The computer doesn't give nonverbals to discourage the student.

As mentioned briefly above, the computer can provide multiple learning styles for the child to learn from. There can be thirty children at thirty different computers studying the same new math problems or reading words in many different ways. The computer is not limited, as a teacher is, to providing only one teaching style to an entire class at one time. With multiple computers, each child can be learning the material in a way that best suits them. As a result, they will learn it faster, enjoy it more, and remember it longer. They will want to learn more because they enjoy learning using a computer. A computer can be as flexible as the hardware and software allows.

B. DISADVANTAGES OF USING A COMPUTER FOR TEACHING AND LEARNING

Although teaching through a computer has many advantages, there are some disadvantages that can greatly detract from the positive aspects. One of these disadvantages is that computers may not be properly worked into the curriculum. It is critical for the teachers to be properly trained on the computer before they can be expected to use it effectively with their students (LESGO2 83, p. 30). The teachers must then take steps to insure that they don't rely too heavily on the computer. While the computer can be very

effective at helping the student learn, the student still needs to learn how to interact with the class - they need to work on other intelligences other than those stimulated by the computer. Among other things, they need to be able to answer questions verbally and to get up in front of their classmates to present information.

A computer cannot replace the human characteristics that are a such an important part of what a teacher brings to a classroom. As stated above, a computer cannot "replace human role models in education, nor is it smart enough to supplant human teachers in their sympathetic interaction with children (LESGO2 83, p. 30)." While a computer can adapt to the user's learning styles, it can't see if the child is getting the answers from his neighbor. It can't tell whether a child is working up to their potential or just doing enough to get by. It can't provide the interpersonal interactions that children receive daily from their classmates and teachers. It is important to remember that computers can be a wonderful learning tool when used properly, but they can not replace a human teacher.

The computer system cannot provide positive non-verbal feedback. Just as the lack of a disappointed look is an advantage, the lack of a warm smile breaking out on the teacher's face after working through a hard problem is a disadvantage.

One of the biggest limits to putting enough computers in every classroom is cost. With decreasing budgets, most schools can't afford to buy computers for every classroom. They generally rely on getting computers through grocery store receipt collection programs, from PTA purchases or from donations. As a result, most schools have a variety of computers, many of them old ones that don't have the capabilities current technology can provide. With this variety of computers, the cost of software and maintenance usually increases because it is not possible to buy site licenses or take advantage of other cost-saving methods. With two of one kind of computer and three of another, etc., the maintenance cost increases because the maintainer has to have a wider variety of spare parts available and technicians must be trained on multiple types of computers. Many times broken computers are just lying around.

Training teachers on multiple platforms also takes more time and can be confusing and discouraging for new users if not done properly. Distributing the computers so that a classroom only gets one type lessens the learning curve for the teacher. However, it makes it more difficult for the teachers to share ideas and the files they've created on other platforms.

C. CHARACTERISTICS OF A GOOD INSTRUCTION PROGRAM

One of the critical elements in the effectiveness of a program is the user interface. If the user is uncomfortable using the program or can't figure it out, he will have a difficult time learning from it. One aspect of the interface is the effective use of multiple senses. By using multiple senses, the user is provided a greater opportunity to learn.

Sight is the most obvious sense used with computers. The user visually sees what is on the screen. It is critical how information is displayed on the screen. The information must be presented in a logical, simple manner that is appropriate for the age of the user. As an example, displaying a clown could be appropriate for a small child, an action figure for an older child and a shiny new sports car for an adult. The complexity of the graphics are important to consider. A detailed picture such as Figure 2 would not be good for a smaller child or one who has attention problems because it would be distracting. In these cases, a more simple picture (Figure 3) is more appropriate. A picture such as the one shown in Figure 3, provides the intended idea of the picture but without over-stimulating or confusing the child. The graphics must support the lesson, not overpower it.

Figure 2 (KIDPI 92): A detailed picture

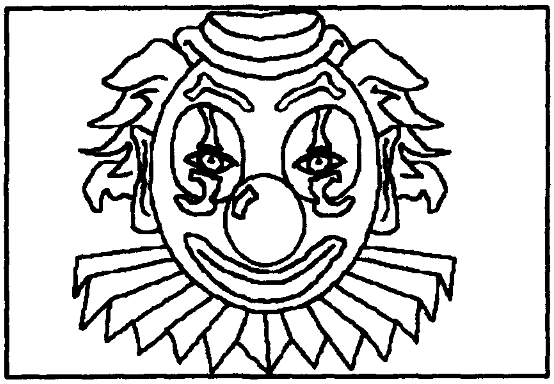


Figure 3 (KIDPI 92): A simplified picture

Overall layout of the screen is also very important for the student. One thing that is important to keep in mind when designing programs for children is that a large amount of text is "inappropriate and daunting to kids (HAKAN 90, p. 124)." At the same time, colorful graphics, sound speech, and animation "are excellent ways to communicate ideas and information... and are attractive to and appropriate for children (HAKAN 90, p. 124)."

Schneiderman provides useful guidance and details on designing the user interface (SCHNE 92).

Sound can be used to provide response stimulus to the student, or with additional equipment, can provide simple two-way communication. For most systems, it is used simply to provide auditory feedback to the user. It can be used as a reward, to add stimulus to the program or to provide clues for the next action to be taken. If a text-to-speech synthesizer is used, text on the screen can be read to the user. This allows instructions to be read to the student that is having trouble reading them. A young student delights in hearing a story that he has just written read back to him by the computer.

If speech recognition is incorporated into the system, the program will be able to "listen" to what the child is reading or saying and provide an appropriate response. For example, if a child is trying to read the word dog and says "duck" the system could respond by saying something like, "A duck goes quack, quack. This animal says bow wow. Please try again." This would allow an auditory response for the user. When used with a visual response, the user will be more likely to understand that he made an error and be able to correct it. These multi-sensory outputs will also give the user more ways to remember the information once learned. By saying it, hearing it, and seeing it the user will more likely remember it than if only one sense is used in one way.

Although speech recognition will prove to be very useful in the learning process, it is still relatively new, and imperfect. Natural language recognition is a very complex task. When creating the software, it will be desirable to provide the capability to use speech recognition if the user has it, but still make the software usable without it.

The last sense that is used when interacting with a computer is touch. It is not used in as many ways as seeing and hearing are. Touch is primarily used in input. Most people use either a keyboard, mouse or a trackball. An attachment that works well with younger children or with handicapped people is a touch screen. It allows the user to touch the screen for the correct answer instead of having to manipulate a mouse or press a specific key. If the child is told to find the letter B, for example, all he has to do is touch it on the screen.

This can be much easier than finding it on the keyboard or coordinating movement of little hands to move the mouse and press the mouse button. Unless one objective of the program is to learn where the letters are on the keyboard or learn how to use a mouse, the touchscreen can be a good alternative. It is wise to use it as an option in any program targeted at this audience.

Another peripheral that works well for younger children is the Intellikeys keyboard (INTEL). It comes with customized keyboards, or new keyboard templates can be created with the software that comes with it. It allows customizing the keyboard to the specific program or user. Younger children do not have the fine motor skills that older children do. For the younger children, the keyboard can be made with large letters in the order of the alphabet instead of the QWERTY keyboard order. This allows them to concentrate on the information they are trying to learn without fighting an input obstacle. Many new software packages are being shipped with Intellikeys templates. Intellikeys use is another option that should be programmed into a good, flexible software package.

In addition to considering input and output options to make the program easy and fun for the young student to use, it is also very important to look at the structure of the program. Thomas Malone defined four principles of instructional design that are necessary to build effective educational software: the perspectives principle, the autotelic principle, the productive principle, and the personalization principle (MALON 84, pp 71-72).

The perspectives principle claims that if the user can approach the subject matter from as many of the following perspectives as possible, there will be more rapid and deeper learning. The four perspectives are agent, patient, reciprocator, and referee. For example, learning to read can be enhanced by having the child write letters to a pen pal (agent), and reading the return letters (reciprocation).

The autotelic principle states that it is important to let a student learn new skills without serious consequences, but once the new skills are learned it is important to provide serious competition (MALON 84, p. 72). This allows the student to overcome the learning curve without the fear of failure preventing him from continuing with the program. Once

he learns the basic skills, the practice drills can become more complicated and challenging to keep his interest and expand his learning. This concept is incorporated into the sample program explained in Chapter VI through the use of activity levels and increasing levels of difficulty.

The productive principle says that learning is more efficient when the student must use what he has already learned to figure out parts of the program or problems he has not yet seen. For example, in the program *Treasure Mathstorm*™ by The Learning Company (LEAR1 92), the user has many increasingly difficult levels to negotiate. One common thread to these levels is putting an equal number of snowballs into three piles to get a prize for each pile. The user can find out how many are needed by capturing an elf who tells him the number. It soon becomes obvious that there are always three piles of snowballs so the user only needs to divide the total number of snowballs found on that level by three to get the number for each pile. The young user does not understand this trick because they are working on simple addition. After they become proficient with the addition, they may discover this trick and with it the beginning concepts of multiplication and division without being told directly.

The personalization principle allows the user to move through the program in their own way, exploring and discovering as they go. It is self-paced and provides the user with immediate feedback to emphasize the user's correct answer or to help them figure out the correct answer if they are having problems. The help is given in increasing increments. Initially the user may just be informed that he is wrong (done indirectly by not moving to next step or not giving the expected reward). If he gets it wrong on his second try, he may be given a clue, and then another, until the computer provides the correct answer complete with an explanation.

Malone provides additional structural features for games (which make very good learning environments for children). (MALON 84, p. 72) They include:

1. Skilled performance is made instrumental to attaining an objective posed by the rules of the game.

2. The game increases in its ability to challenge the player: it does not become boringly simple.

3. The game incorporates fantasy elements (piloting a ship, finding a treasure, etc.).

4. The computer can time the players' responses and calculate scores based in part on quickness of response.

It is essential to balance all aspects of a program to ensure one does not minimize the effectiveness of another. For example, giving the user the freedom to choose their own way around a program can be very appealing and motivational to the user. But structure plays an important part in ensuring that all the necessary material is covered. The two need to be balanced to ensure that both are effective. Malone quotes Groen as saying "Free activity is important, and so is the structure of the environment... Ignoring the second can lead to aimless play. Ignoring the first can lead to a sophisticated curriculum that most students fail to assimilate or understand." (MALON 84, p. 72) The game *Treasure Mathstorm*™ (LEAR1 92) employs these principles well. At each level there are several different tasks that the child can perform to acquire the tools necessary to proceed to the next level. These activities include such tasks as counting, balancing weights or telling time. The program allows the user to choose which activity they want to attempt at each level. As they cycle through the levels, the program keeps track of the players accomplishments and increases the level of difficulty in those activities the player successfully completed on previous attempts. The activities that the player passed by in previous rounds are not changed. Eventually the difference between levels of difficulty become so great that the player is inclined to try the tasks he has been avoiding, because they are now relatively easy. Each of the activities incorporates math problems, just in different ways. The program provides freedom of choice, but almost forces the user to choose multiple activities as a result of the increasing difficulty. This method provides enough structure to ensure all necessary activities are encountered by the user.

D. SUMMARY

This chapter briefly evaluated a few of the characteristics of a good instructional program for children. It showed how a multimedia program can engage more than one of the seven intelligences at a time, and can modify itself to present the lessons in a manner that is most appropriate for the individual student using the computer. By incorporating concepts discussed in earlier chapters, such as motivation and curiosity, the program designer can develop an educational program that is enjoyable by many children and can adapt to their specific needs. The program is well-suited to be used by many of the children called "learning-disabled." The program can also be used by "normal" children in mainstream classrooms to expand their knowledge. These concepts can be used to teach virtually any subject, including reading, math, and history. The utility is limited only by the designer's imagination and programming ability. The next chapter will discuss the overall design of one such program.

V. A SOFTWARE ARCHITECTURE FOR CAPER

This chapter will discuss a model for building a program that will teach students with varying learning styles how to read. This high-level design is limited to discussing the major modules and the essential communications between these modules. It is beyond the scope of this thesis to detail the complete input, process, and outputs for any of these modules. This high-level discussion will explain how the system will operate.

A. SYSTEM OVERVIEW

Many computerized tutoring systems have been developed in the past 20 years (GLYNN 87, pp. 26 - 28). They are referred to by many descriptive terms such as Computer Aided/Assisted Instruction (CAI), Computer-Assisted Learning (CAL), Computer-Based Instruction (CBI), Computer-Based Training (CBT), and Computer-Managed Instruction (CMI) (GODFR 82, p. 4) (ENCYC 83, pp. 292,294,355). These are typically flexible, but pre-determined, ordered sequences of information presented to the student without considering the students personal learning style or current knowledge level.

CAPER belongs in the emerging field of Intelligent Computer-Assisted Learning (ICAL) and Intelligent Computer-Assisted Instruction (ICAI), but until recently when systems became more affordable, most of this work has been done in laboratories (PARK 87, p. 12). The major differences between ICAI/ICAL and CAI/CAL programs relate to the artificial intelligence routines included in ICAI/ICAL systems, which enhances their ability to provide the student with individualized learning tools. Some of the key differences are: (BEGG 87, p. 324) (PARK 87, p. 31)

1. The author defines the knowledge network and inference rules but not the detailed instructional sequence.
2. A model of student performance is dynamically maintained and used to drive the instructional sequence.

3. Students can ask sophisticated questions or pose problems (characteristic of 'mixed-initiative tutors').

4. The tutor provides diagnostics of student errors (characteristic of 'coaches').

Many different ICAL programs have been developed during the past ten years (BEGG 87, p. 323) (WOOLF 87, p. 230). All of the ICAL programs build upon the same basic components, although each program emphasizes the basic components to varying degrees and in different ways (PARK 87, p. 18) (BEGG 87, p. 325). The basic components include:

1. Domain expert, knowledge network, expertise module
2. Student model
3. Error/diagnostic rules, diagnostic expert
4. Teaching expert, teaching rules, tutorial module
5. Student-tutor interface (BEGG 87, p. 325) (PARK 87, p. 11) (VASSI 92, p. 581).

The basic system model (Figure 4) used in this thesis is a blend of many different models, depicting the concepts that best suit the needs of this program (BEGG 87, p. 326) (WALLA 87, p. 307) (PARK 87, p. 38) (HAYAS 92, p. 279) (NODEN 92, p. 533) (VASSI 92, p. 583) (WOOLF 87, p. 234). It should be noted that this model is dynamic in that each user response will not only update the current user model, but also affect the interpretation and resolution of *subsequent interactions* (WOOLF 92, p. 58). The following sections will explain each of the components of the model and how it interacts with the overall model. The components will be illustrated using the application of teaching young students to read.

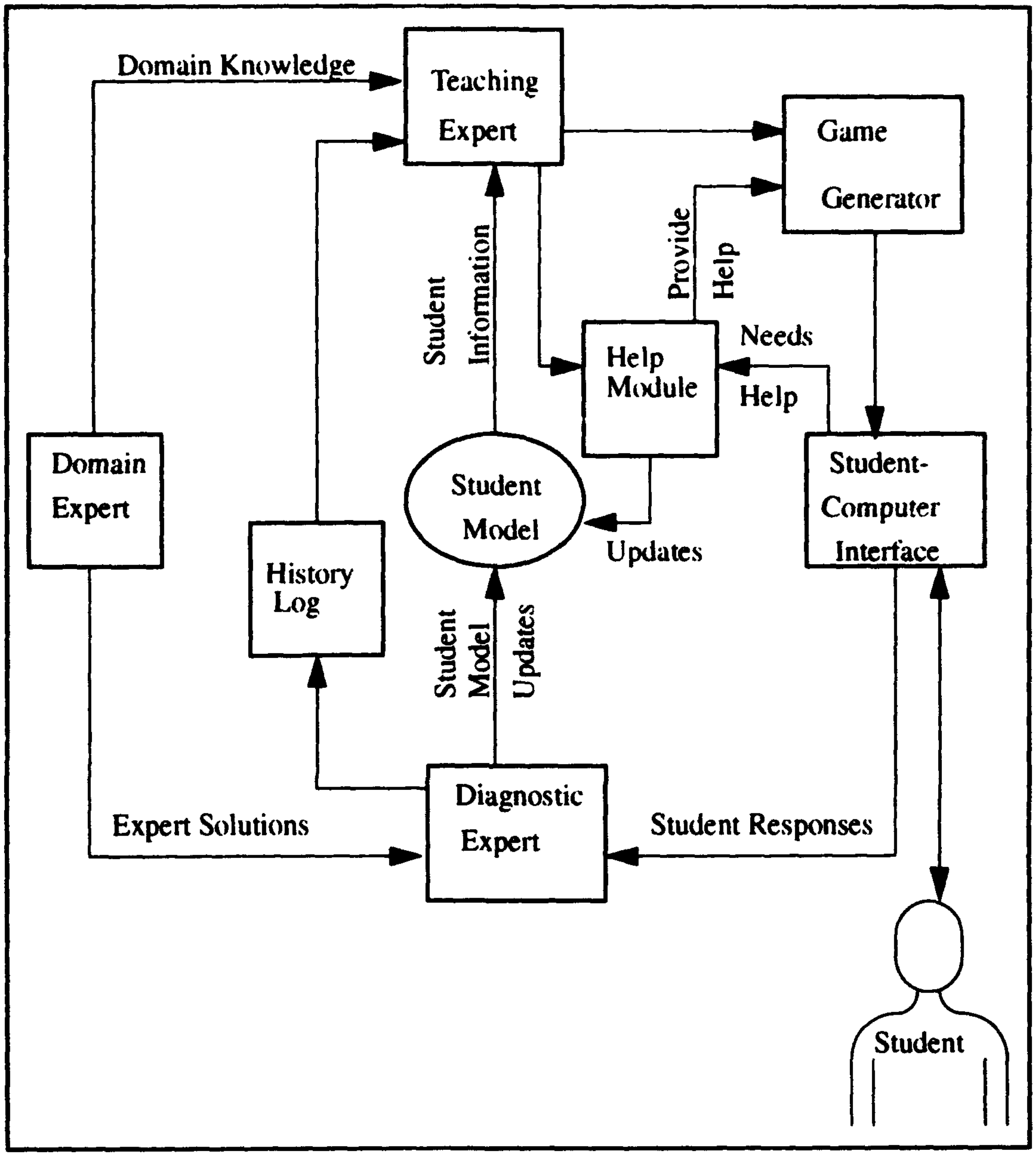
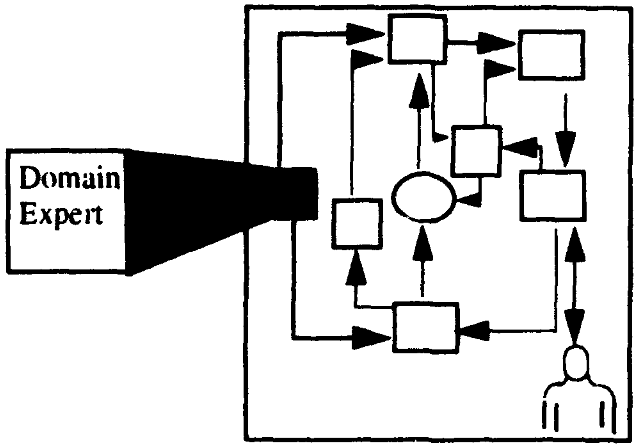


Figure 4: CAPER system model

B. THE DOMAIN EXPERT/DOMAIN KNOWLEDGE BASE



The domain expert is more than just a list of the facts that the student needs to learn. It stores the concepts, activities, inter-topic relationships, and rules that are needed to make expert decisions (BEGG 87, p. 325) (WOOLF 92, p. 48) (WOOLF 87, pp. 229-230). To apply this component of the model to the concept of learning to read, the information to be learned must first be determined. The other aspects of this component can then be discussed using the specified information.

The primary precursor concepts that must be mastered prior to learning to read are letter identification, letter sound (phonics), word recognition and simple sentence construction. These concepts fall into two categories - letters and words. The order in which these areas are learned depends on the student and their individual learning style. Many times a spatially-oriented person will find it easier to learn words before letters. They think in images and pictures. As a result, it is easier for them to link a whole word with a picture (Figure 1). A letter by itself has little meaning for a spatially-oriented person. On the other hand, linguistically and logically-mathematically oriented children tend to learn to read more easily beginning with letters. A linguistic child is sensitive to sounds, structure, meanings and functions of words and language (ARMST 93) so they can learn how words are built from the individual letters. The logical-mathematical person is good with patterns so they can learn how letters form different patterns or words. Since some children find it

easier to learn to read by learning letters first and others by learning the words first, neither can be a prerequisite for the other. CAPER determines which way the child learns best and presents the information in that order. As a result, each are handled somewhat separately in this thesis. Either the child will learn letters first or words first (Figure 5).

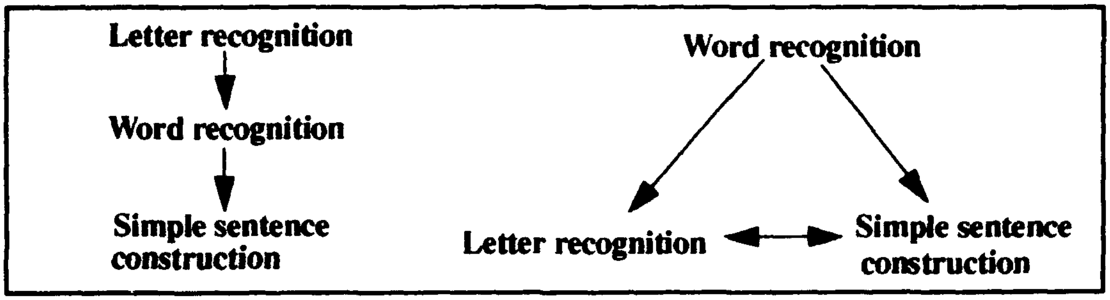


Figure 5: Varied paths to sentence construction

A child that learns letters first will progress to words next and then to sentences. However, a child that learns words first can then "backtrack" and learn letters and also learn simple sentence construction. For him, word recognition is a prerequisite for both subjects.

Now that the overall hierarchy has been mapped, it is necessary to look more closely at each area. Letter recognition includes learning each letter by sight and by sound as well as the order of the letters in the alphabet. Each of these ideas can be represented (and stored[1]) in an array similar to the one in Table 1.

The overall hierarchy used to determine the order of presentation of the material is shown in Figure 6. This shows the prerequisites needed before a new topic can be presented. It shows that alphabetical order can be learned either after visual identification or sound identification is learned. Both are not needed to learn the order of the alphabet. However, visual and sound identification could be learned in parallel and both help in learning the alphabetical order.

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1. This is a very simple way to store the information. It is sufficient for the high-level design presented in this paper. More complex methods are being researched and developed for use with learning systems (VASSI 92, pp. 584-589).

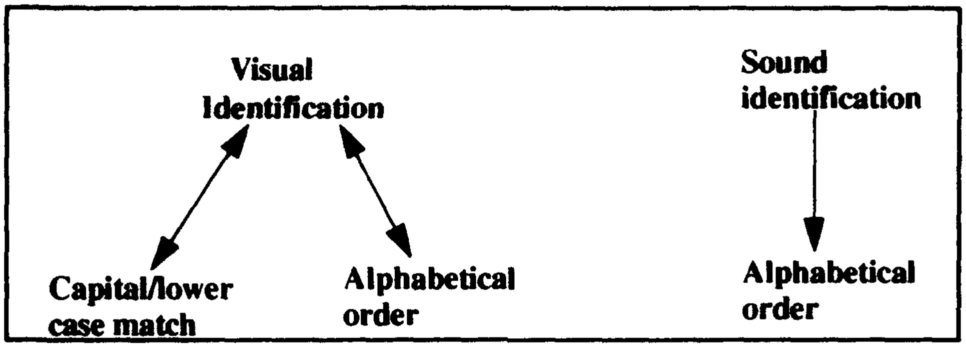


Figure 6: Letter recognition hierarchy

	Visual Identification	Sound Identification	Capital/lower recognition[a]	Alphabetical order
A				
B				
C				
. . .				
Z				
a				
b				
c				
. . .				
z				

Table 1: Storage array for letter knowledge

a. Given an 'A' and recognizing 'a' would put a mark in row 'A'. Given an 'a' and recognizing 'A' would put a mark in row 'a'.

Figure 6 also shows that a student must know how to visually recognize each letter before he can learn to match the lower case letter with its respective upper case letter or learn the alphabetical order of that letter. In general, this is true. However, he doesn't need

to know the letter 'Z' to be able to match 'A' and 'a' together. He only needs to be able to recognize the 'A' and 'a'. As a result, the hierarchy chart in Figure 6 needs to be broken down into more detail to accurately define all prerequisites (Figure 7). Figure 7 shows the

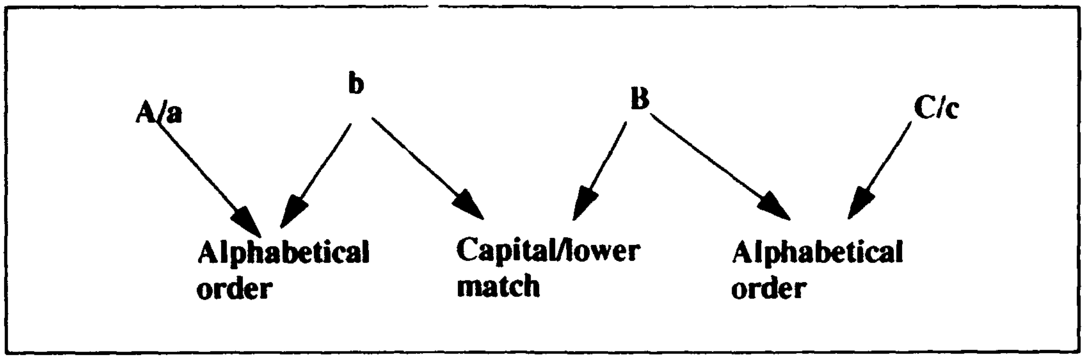


Figure 7: Visual letter recognition

prerequisites needed to learn everything visually about the letter 'B' (Sound is similar to this except that it does not have to differentiate between upper and lower case. But it does have to address the multiple sounds one letter may have.) It shows that the student must recognize both the 'b' and 'B' before he will be able to match them together as a pair (upper and lower case). It also shows that the student must know what an 'A' is, either upper or lower case, before he can learn B's order in the alphabet in relation to it. The same is true for the letter 'C'. It also shows that the user doesn't necessarily need to know both the upper and lower case of a letter to learn it's alphabetical order and that when learning the alphabetical order, it can be mixed between upper and lower case.

Word recognition requires that a student learn words by sight and sound like letter recognition requires. Again, neither one has to precede the other. They can be learned totally independently or in parallel with each other (Figure 8). Generally, students have already learned quite a substantial vocabulary by the time they begin to learn to read. As a result, they only need to learn many words by sight. New words that they are not familiar with need to be learned by both sight and sound. Once a student has learned words by either sight or sound, he can learn how to put the words together to form simple sentences. It is important to realize that sentence construction is totally separate for sight and sound. Just

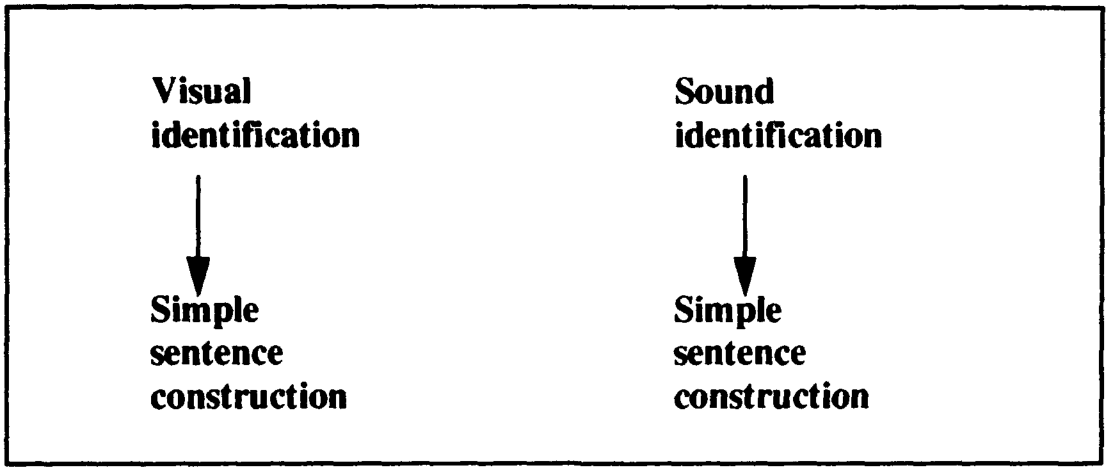


Figure 8: Word recognition hierarchy

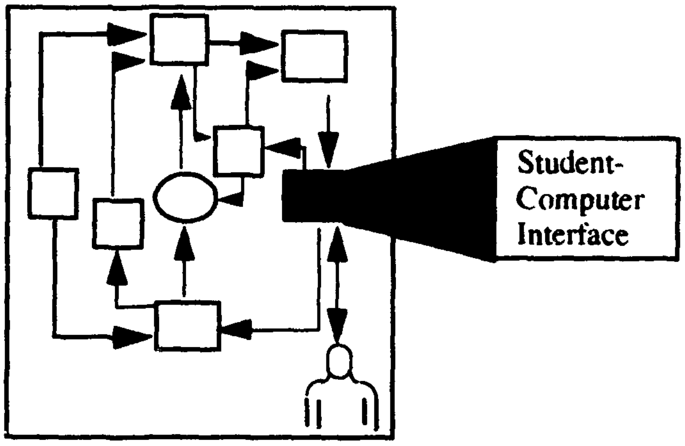
because a person can talk in sentences, does not mean he can read the sentences. That is why the skills are separate in Figure 8. CAPER keeps track of what words the student knows. It does that in a way similar to letter recognition (Table 2).

	Visual identification	Sound identification	Simple sentences
dog			
cat			
up			
down			
ran			
the			
bat			
sat			
boy			
. . .			

Table 2: Storage array for word knowledge

This section has described some of the information that must be maintained in the domain expert. The next section will provide a high level description of the student-computer interface. It will provide an overview of what the interface is composed of and some necessary considerations to insure it is effective.

C. THE STUDENT-COMPUTER INTERFACE

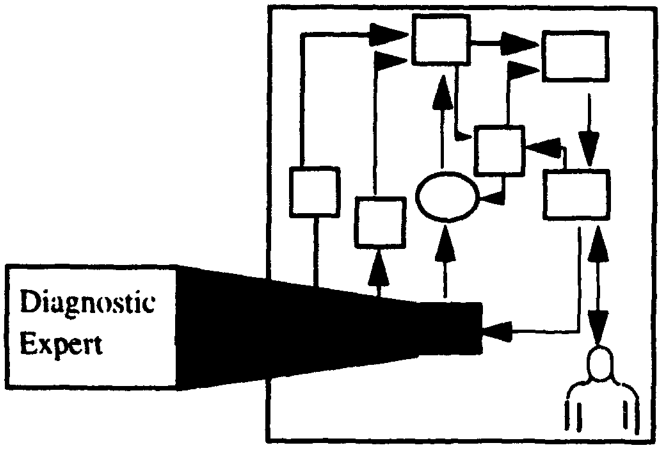


The student-computer interface is the input/output component that enables the user to communicate with the program in as transparent a way as possible. It ensures that the machine and the software that allows the student to communicate with the machine is presented to the student in a manner that does not hinder the user from attaining the goals of the software package. A perfect interface is not noticed by the user. It is totally transparent and thus allows the student to maximize the benefits of the software package.

Beyond the actual interface with the student, this module will also contain all machine specific elements involved in input/output operations. Those include, but are not limited to, drivers for graphics, sound, printers, video, keyboard, mouse, and touch screen. Putting all of these in one module makes it easier to modify the program for use on multiple platforms.

D. THE DIAGNOSTIC EXPERT

The diagnostic expert can be compared to a coach. It looks at the responses from the student, determines what the student's learning needs are and provides the student with



appropriate feedback to assist them in the learning process. This is anything from just letting the student know an answer is wrong to providing the correct answer with an explanation. The response is dependent on the current situation in the game and the rules set up in the software to determine the appropriate response. The diagnostic expert also updates the student model with current information from the student's responses. (PARK 87, p. 31,37) (BEGG 87, p. 325) (WALLA 87, p. 307)

A basic layout of the diagnostic expert is shown in Figure 9. It only shows one topic being expanded (Visual ID letter). Other topics from Figures 6 and 8 have not been expanded. The diagnostic expert receives input from both the domain expert and the student. It checks to see if the student's answer is correct. If it is correct, it tells the system to give an appropriate, motivating response for the correct answer, it updates the student model and history log and then it continues to the next question which is determined by the teaching expert. If the answer is incorrect, the system begins to evaluate the response. First, it determines the type of problem the student was doing and the question asked. With this information, it finds an appropriate response for the student based upon the expert's answer and the student's response. This section of the diagnostic expert can be quite complex with many rules to determine the appropriate response. In this system however, the questions are simple compared to systems designed to tutor algebra, physics or some more complex subject. Also, since the student does not yet know how to read, the degree of text based

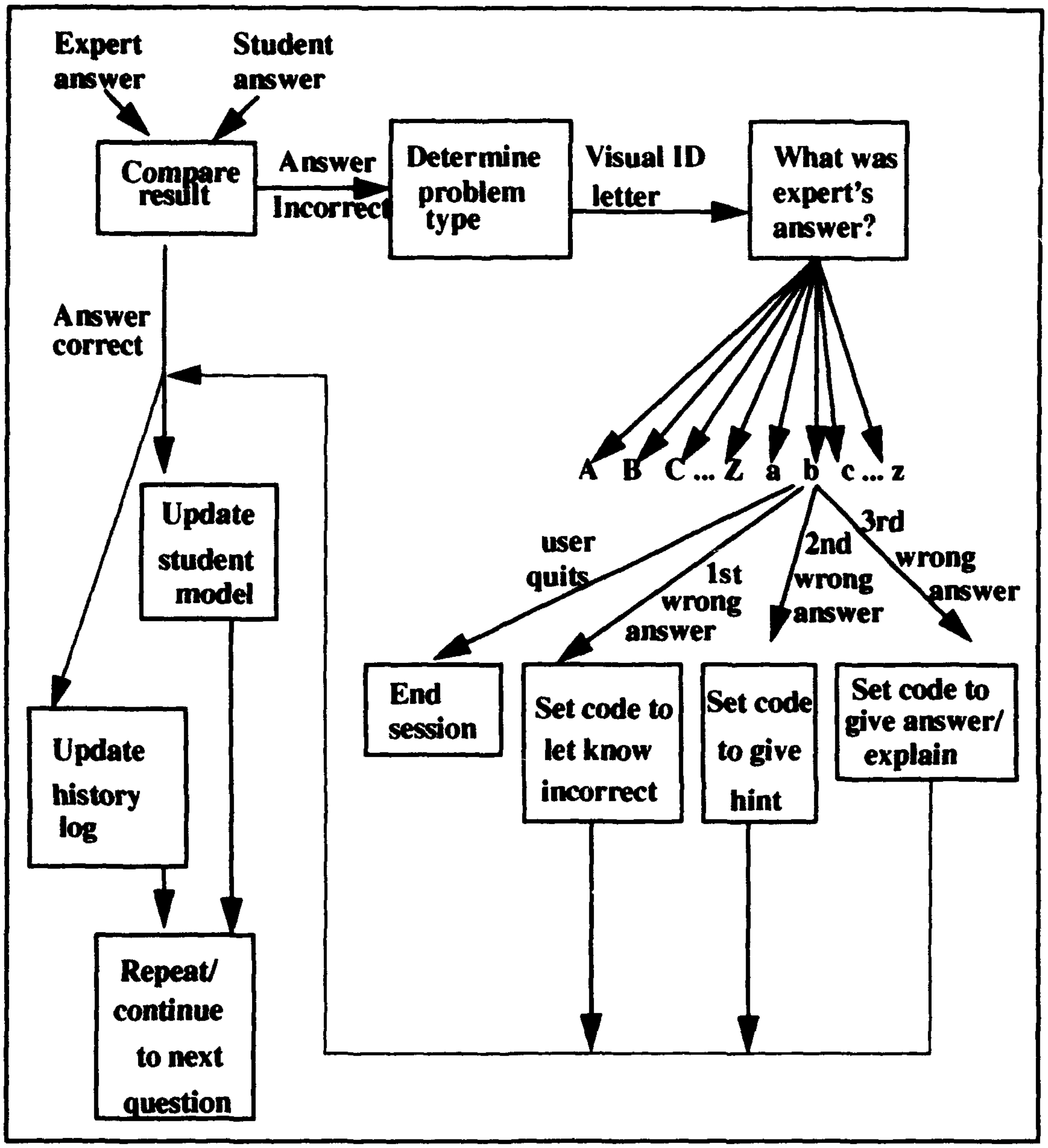


Figure 9: The diagnostic expert

communication that can occur with literate students cannot take place here. A verbal method of output and icon based method for input is used.

As discussed in earlier chapters, responses to the student should not be belittling. The first response to an incorrect answer is a simple indication that the answer was incorrect. If there is a help or mentor character in the current game, the character can simply shake his

head no. indicating an incorrect response. If the student is supposed to choose a letter and he chooses an incorrect one, it either disappears or changes color to indicate an incorrect answer.

For a second incorrect response, the system not only lets the student know the answer is incorrect, but it also provides some hint to help them figure out the correct answer. It may cause "correct" letters to blink, highlighting the correct choice(s). It may also give the student a verbal message indicating what they are supposed to do if the system believes they are confused or it may give them a hint on where to look (for example: look in the bushes) if they are searching for something. The objective here is to assist the student without revealing the answer. It is important that this hint be done in a manner that is either positive or neutral, but not belittling.

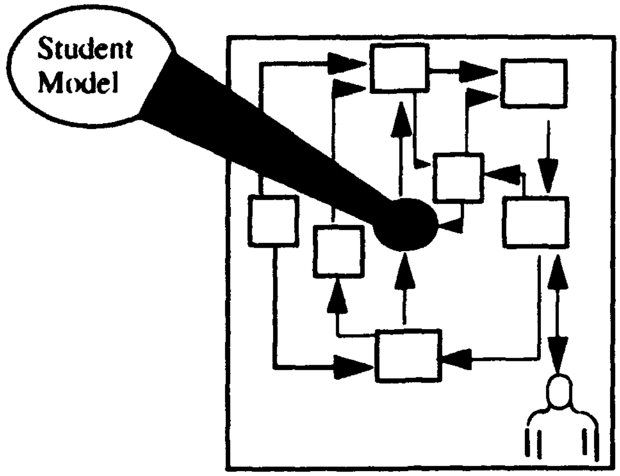
For a third incorrect response, the system reveals the correct answer and provides a simple explanation in a positive, entertaining way. This allows the student to learn what the correct answer is and why it is correct. The principle is to help him learn the correct answer in a manner that improves his chances of answering correctly the next time without fearing the response if his next answer is incorrect.

To keep track of what question the student is on, what game is being played, how many guesses the user has made for the current question and what the next action to be done by the system is, an information packet is passed throughout the system indicating the current scenario. That information is easily passed through the system as a record containing the following fields: question_num, game_num, attempt_num, and next_action. Question_num contains a number corresponding to the piece of information to be taught in that lesson. It could be the visual recognition of a specific letter or the ability to match a capital letter with its lower case counterpart. Game_num contains the number of the type game that is currently being used to teach the specific lesson. Each lesson can be taught using a variety of games which the user can choose depending on his preferences at that time. Attempt_num keeps track of how many tries the user has made at the current question. A '1' indicates the first try, a '2' indicates the second try, a'3' indicates the third try, a '4'

indicates a wrong answer after 3 tries, and a '5' indicates the user chose to quit playing before a correct answer was given. This information is used by the teaching, diagnostic, and domain experts to assess the student's level of expertise and to determine the appropriate response.

Next_action contains information on what action the system should perform next. Possible options include continue, the type of response to give for an incorrect answer, and whether the system should suggest a new game or let the student choose a new game. Continue means the student is done with the current question and the teaching expert needs to select a new question. Type_of_response informs the system what type of response should be presented to the user based on receiving an incorrect answer and the game currently being used. Suggest_new_game is used when the user is not making any progress on the current game or when he completes the current game. CAPER encourages the user to choose a new game from games that meet the students current learning style. In this way, the student is presented the same or similar material in a game that is more suited to him at the time.

E. THE STUDENT MODEL



The student model is a "representation of what the student has learned or currently knows (as perceived by the ICAL system (WALLA 87, p. 306))... and is maintained dynamically and used to drive the instructional sequence (BEGG 87, pp. 324-325). It also contains information about the student such as their preferred learning style(s) (PARK 87, p. 38). Understanding the student's learning style, as discussed in earlier chapters, is key to presenting him new material in a meaningful and enjoyable manner tailored to him as an individual. With an understanding of what the student knows and how he likes to learn, the teaching expert is able to taylor lessons to the student's specific needs.

To maintain a list of information the student already knows, the system keeps track using tables such as those in Tables 1 and 2 on pages 46 and 48. Using the same tables allows the system to overlay the student model onto the domain expert to determine what the student does not know yet. There are many ways to keep track of what a student knows and how well he knows it. It is important to realize that a student doesn't necessarily just know or not know a piece of information. He could have partial understanding. Some of the quantitative states could be listed as 1) a topic is generally known, 2) the student has background information, and 3) the student is confused (WOOLF 87, p. 257). One method to keep track of how well a student knows a piece of information is to assign a numerical value to it. For example, if a student answers a question correctly on the first try, a '1' is

added to whatever value is in the table for that piece of information. A correct answer on the second try is worth 0.5, a correct answer on the third try is worth 0 and missing the question 3 times causes 1 point to be subtracted from the value in the table. The teaching expert then evaluates the total for each piece of information and decides whether it is known and doesn't have to be taught anymore, except for review, or if a student needs work on a particular piece of information. The teaching expert then posts that decision in the student model.

In addition to maintaining the domain of student knowledge, it is very important to maintain a record of the student's preferred learning style at the individual question level, at the general question type level and overall. The records by question type and overall are done by making a two-dimensional array as shown in Table 10. From this array, the system

	Spatial	Linguistic	Math/ logical	Body/ kinesthetic	Musical	Inter-personal	Intra-personal
Visual ID letters							
Sound ID letters							
Capital/ lower match							
Alpha order							
Visual ID words							
Sound ID words							
Simple sentence construction							
TOTAL							

Table 3: Learning style records

makes a quick determination of the student's overall learning style(s) or his preferred

learning style(s) for a specific subject. Values are added to each cell (Table 3) depending on which game the student is playing and how many times it takes to get a correct answer for the question. Each game used has up to four learning styles associated with it. Each learning style is listed according to its dominance in the game. Values obtained from Table 4 are

	First try correct	Second try correct	Third try correct	Fourth try correct	User quit
Strongest intelligence	1	.5	0	-1	0
Middle high	.75	.375	0	-.75	0
Middle low	.5	.25	0	-.5	0
Weakest intelligence	.25	.125	0	-.25	0

Table 4: Intelligence scores

added to Table 3. With this information, the system is able to link a question given to a game that most closely meets the student's learning style. All cell entries are divided by ten when one cell reaches 100. This keeps the numbers in Table 3 relative to each other without allowing the values to become too large. CAPER is able to do a quick search of the table to determine the dominant learning style(s) by finding the highest number in a specific row.

Keeping track of each question by learning style and accessing that information is done in a manner similar to Table 3. However, the table is different because different information is used. It is similar to Table 1 with a third dimension for learning style added (Figure 10).

This section has looked at the student model. The next section will describe how the teaching expert uses information from the student model, the domain expert and a history log to determine the student's next question.

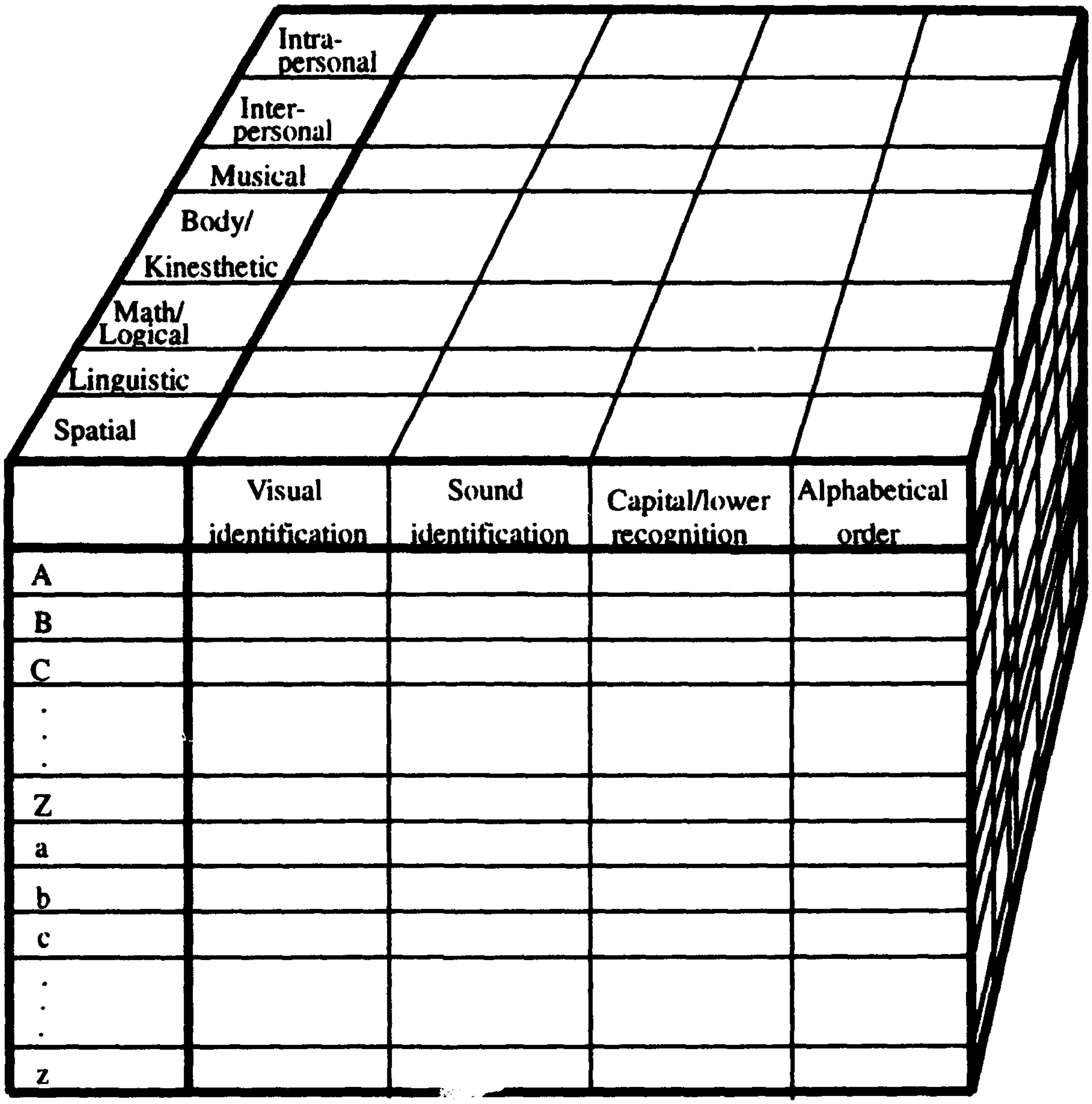
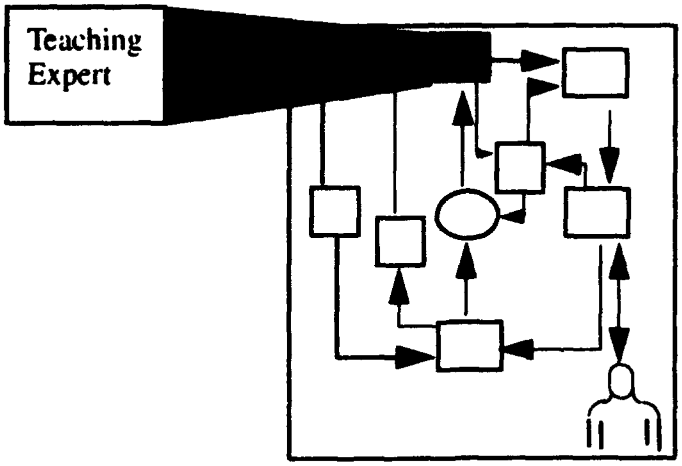


Figure 10: Three-dimensional learning record

F. THE TEACHING EXPERT



The teaching expert uses the latest information in the student model to determine what the student still needs to learn, when the student needs to learn it, and how it should be presented. Figure 11 depicts the high level interaction within the teaching expert (PARK 87, p. 17) (BEGG 87, p. 323) (WOOLF 87, p. 229) (WALLA 87, p. 306).The teaching expert determines what the student must learn by overlaying the array of what the student currently knows onto the array of all the knowledge that must be known. It then receives input from the diagnostic expert through the student model which it uses to determine what type of action to initiate next. If the appropriate action is to present another question, the teaching expert then decides what needs to be learned next based on prerequisites and the student's current interests.

Once the teaching expert determines the information that the student needs to learn, it chooses which learning style to deliver the question in. The style it chooses is not always the student's dominant learning style. The teaching expert often uses one of the weaker styles to develop all of the student's styles. When weaker styles are used, the tasks presented usually are ones where the student has already demonstrated that he generally knows the task through other learning styles. Allowing the student to answer questions that he already knows, but which are presented in one of his weaker learning styles, provides an opportunity to become more familiar with that learning style, build his self-confidence

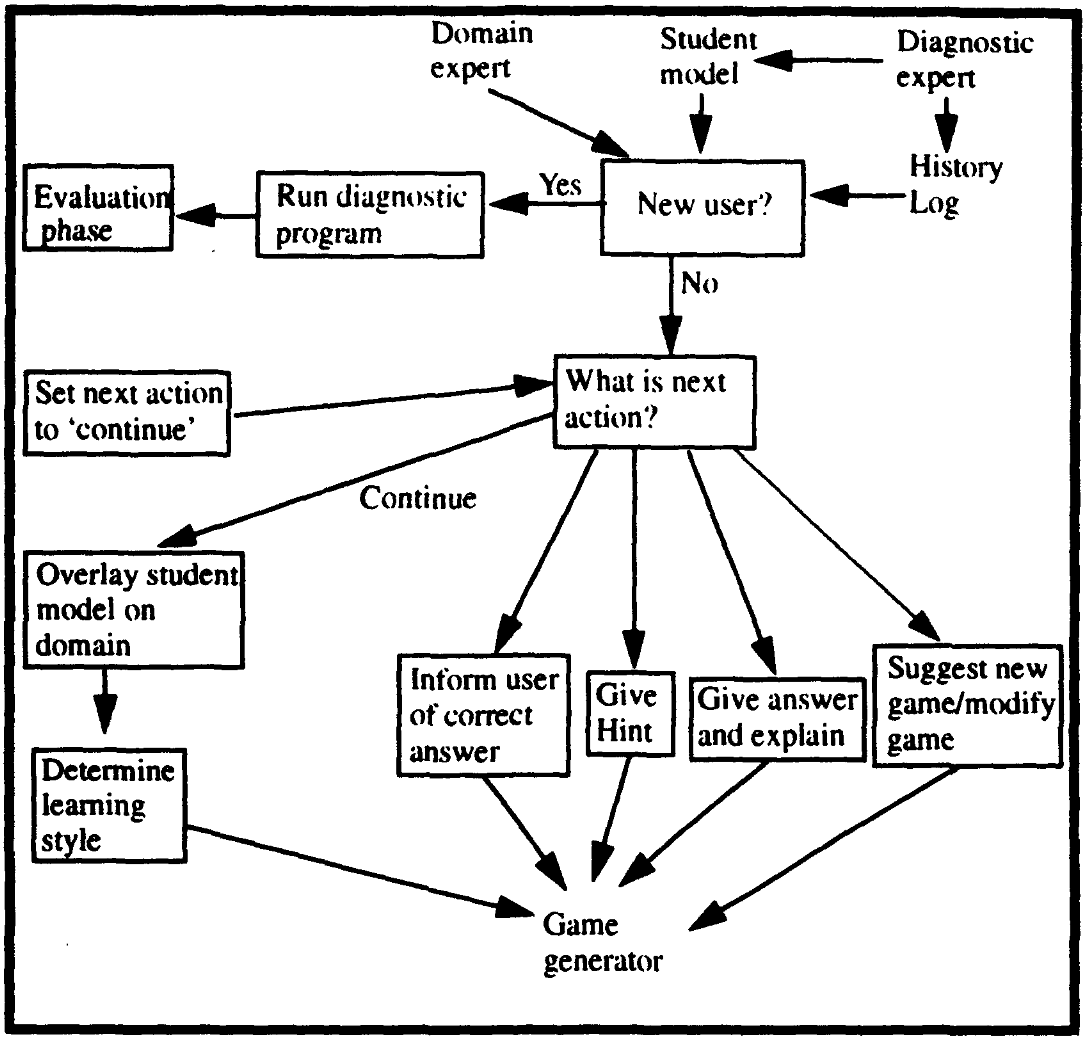


Figure 11: The teaching expert

using that learning style and to ultimately increase his strength with that learning style. Once the question and the game to be used have been determined, the game generator takes over (see next section).

After a game is initiated, the teaching expert does not change to a different game until the student quits the first game[2]. It can, however, modify the current game by adding or

2. The teaching expert may recommend to the student that he switch to another game, but it is up to the student to make the change.

deleting elements from the screen. For example, it may remove some of the extra images from a forest scene if the student's responses indicate distraction or confusion.

If the next action required of the teaching expert is to let the user know he has a correct answer, the teaching expert decides how to do this weighing the student's learning style and the current game. Sometimes the system rewards the student with game money or prizes. At other times game characters jump up and down or do flips, sing a quick musical chant, the mentor may just nod his head, or a new question may just appear. The action chosen incorporates information from the student's learning style, the current game and motivational topics discussed in earlier chapters (WOOLF 87, p. 241).

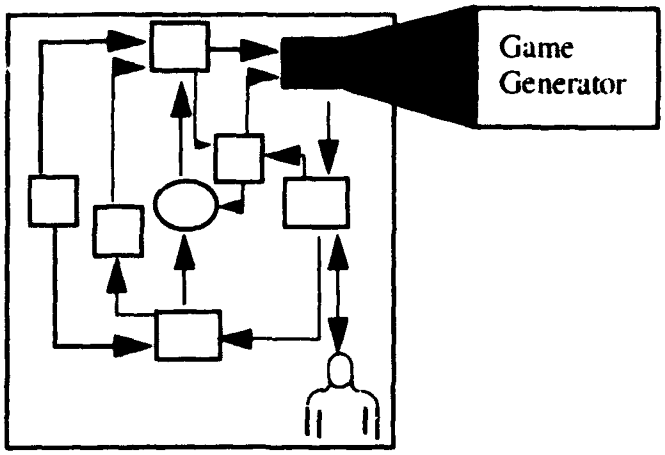
If the next action is to give a hint or provide the answer and explanation, the system again uses the student's learning style and the current game to determine the type of hint to give. The hints can be one of four types: verbose, brief, socratic, or coaching (WOOLF 92, p. 56) (PARK 87, pp. 17-18). A socratic response provides the student with questions that help them figure out why the response was incorrect. The coaching response is designed to help the student in an enjoyable and educational way. Verbose and brief are self-explanatory. Verbose is used only periodically with linguistic students.

The previous actions explain what the system does if the student is in the middle of the game. In the special case of a new user, a diagnostic is first run to help ensure the user has a basic grasp of how to use the various input devices so the next step, the evaluation, is as accurate as possible. The diagnostic is a series of games that the student plays using the keyboard, mouse and/or touch screen. If it is clear that the user knows how to use them, the diagnostic is short. However, if the student doesn't know how to use the input devices, the diagnostic runs an introduction routine to familiarize the student with the input devices.

After the diagnostic has been completed, the student is presented the evaluation phase which is used to build a baseline student model. Again, this is a series of different games that will allow the student to choose among the various learning styles and lesson topics and CAPER evaluates the quality of the responses. Once the evaluation phase is complete, the new user advances to the regular games as explained above. When the teaching expert

has decided what actions need to be taken and how to proceed, it passes that information to the game generator.

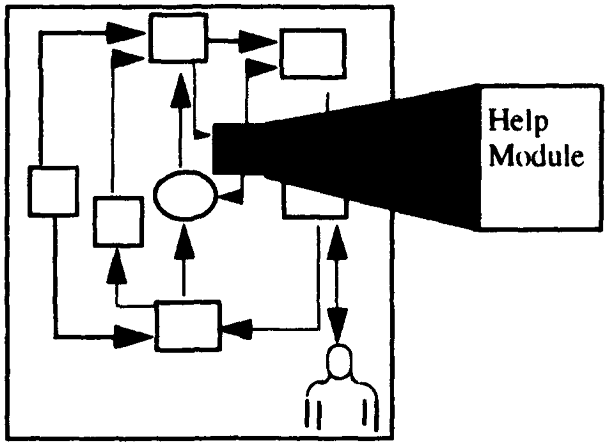
G. THE GAME GENERATOR



The game generator integrates the information and instructions that it receives from the teaching expert and help module and designs the presentation. The game generator uses a collection of graphics and sounds that it must organize and present according to the information it receives. If a game is in progress, the game generator must know to continue to use the same characters and game rules to provide continuity and minimize confusion. It can however change subtle elements such as the complexity of the display or the way a response is provided to the student based on the information it has received from the teaching expert or help module.

If the student is switching from one game to another, CAPER is able to display the game the teaching expert chooses with the various objects and sounds the teaching expert determines are appropriate. The teaching expert can be referred to as the brains because it decides what to do and how to do it, while the game generator can be referred to as the braun because it does the work to implement what the teaching expert has directed it to.

H. THE HELP MODULE



The help module (Figure 12) provides help to the user when it is specifically requested

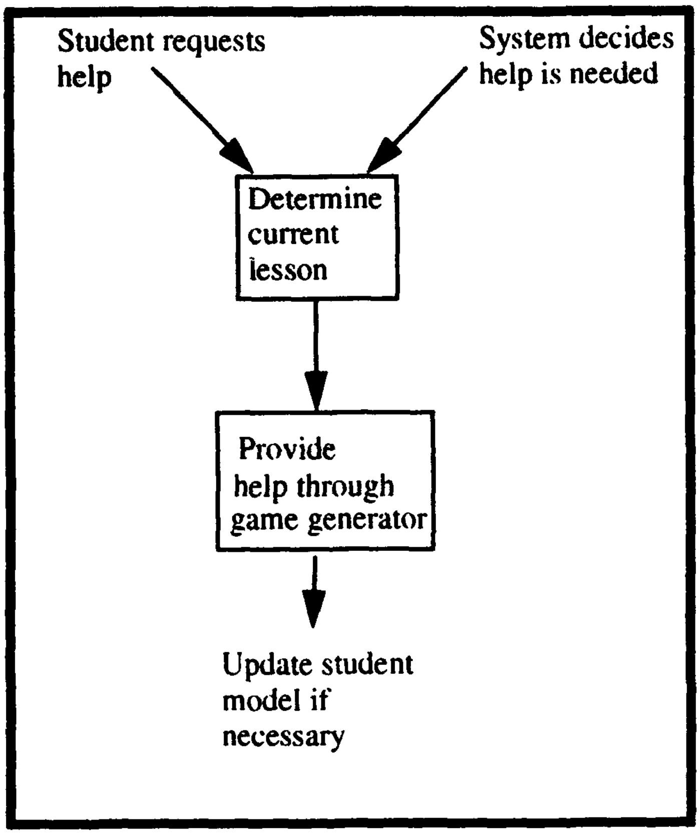
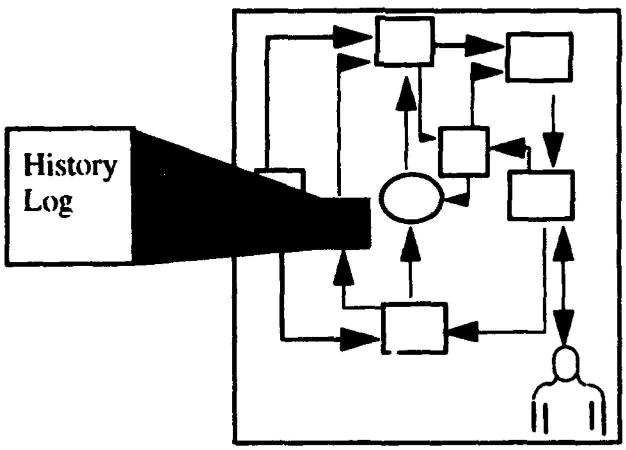


Figure 12: The help module

or because CAPER determines that the student is confused and needs help. It is important to remember that the student doesn't know how to read. As a result, all help must be provided through animation and/or sound. The help module can be initiated by either the teaching expert or by the student. The student is able to request help by clicking on a character (such as a wise owl) that is constant throughout the game. CAPER may decide the user needs help based on an analysis of the history log. For instance, missing several questions in a row is an indication that the student needs help.

Once help has been requested, the help module determines the content, the question being asked, and the current game. From there it provides help, through the game generator, based on the current scenario. Occasionally, it has to update the student model when it has been determined that the student missed previous questions because he didn't understand what he was supposed to do instead of not knowing the answers.

I. THE HISTORY LOG



The history log is used to maintain a history of actions performed by CAPER and a history of the student's responses. The information is used to determine characteristics of the current session that may differ from the overall student model. The student's learning style preference may vary from session to session, or even during a session (BOYD 92, p. 23). This variance can be detected by looking at recent actions and responses and

comparing them with the overall record. With this information, the teaching expert adapts to the student's current learning style providing the most effective learning environment.

J. SUMMARY

This chapter has laid out a high-level concept of how CAPER teaches to the specific needs of the individual student and his current learning style. It is important to note that concepts form the first four chapters are included to ensure the material is presented in a challenging, motivating and effective manner. By blending this information together into one program, a highly effective teaching tool is developed to not only help the so-called learning disabled student, but also the "normal" student. The next chapter will discuss a sample program in which these concepts is implemented.

VI. SAMPLE APPLICATION

This chapter illustrates how CAPER teaches reading skills beginning with letter recognition and progressing to sentence construction. CAPER is suitable for children of widely varying abilities and different dominant intelligences. CAPER evaluates the abilities and relative strengths of the seven different intelligences (see Appendix A). It then modifies the core program to provide the optimum learning environment for each student that uses it. This description illustrates the concepts of CAPER but does not describe the entire program. The objective program requires many more levels, or years, and the user interface requires further development. Additional creativity is needed to enhance the transitions and improve the overall program.

A. OVERVIEW

This program description uses the theme of the seasons of the year as the basis for embedding lessons to teach students in kindergarten or first grade to read. The program is a quest style adventure game that is highly interactive. The students try to advance in grade by collecting prizes and earning keys to advance from one season, or level, to the next. The game challenges the student to accomplish many tasks with rewards for successful completion. The rewards vary and are context sensitive. The only punishment is the lack of a prize or advancement. The seasons provide different sets of skills with each skill set having certain task choices. The level of difficulty is increased each time the student progresses through a year, crossing from winter back into spring. The increases are limited to those tasks that the student successfully completed during the previous cycle. This encourages the student to move to tasks that he avoided during earlier rounds as the difference between difficulty levels increases.

There is a wide-ranging cast of characters that can be brought into the story depending on how the teaching expert designs the lesson plan. The teaching expert determines the

styles in which the lessons are presented. Within the overall framework, the student chooses paths and screens, based on his preferences. Though there are many paths and tremendous variance possible on each path, all of the skills necessary for reading are taught and the student's ability evaluated until the student can read at the first grade level.

The diagnostic and teaching experts are self-tailoring modules that identify the strengths and weaknesses of individual students and modify the core lessons and interfaces to capitalize on his strengths so as to maximize learning. The game cycles through the four seasons over and over again presenting the student with varied games to play that convey the basic elements of vocabulary, spelling, and sentence structure.

The program employs an expert system decision aid and object-oriented programming techniques to modify the presentations. The first time the student signs onto the system he begins by playing two introductory sets of games. The first ensures that he is familiar with the input devices and can follow the programs instructions. The second evaluates what he likes and how well he can perform in the game with his choices. This is done by having him select different scenarios and then evaluating how well he performs in each. The differences between the scenes include such things as the number of objects on the screen at one time, the amount of movement, the amount of sound, and the type of help that is offered.

Some of the assumptions made in writing these specifications are:

1. The student chooses options that emphasize the dominant intelligences because that is what they do well.
2. While not all students are proficient at reciting the alphabet, all students are familiar with it.
3. Involving more than one intelligence at a time in a game is always better than involving only one. This allows the student to do well if he is strong in either of the styles presented.

B. PROGRAM DESCRIPTION

These specifications call for a program that is based on an expert system. The expert system is responsible for evaluating the students responses, both during the initial

diagnostic game and during the lessons. Based on these evaluations, the teaching expert decides on the initial lesson plan and subsequent modifications. The teaching expert orchestrates many subordinate programs, controlling the order, intensity and level of difficulty.

1. Sign On

Each student has a personal student model that is selected when he logs onto the system. This model includes the intelligences hierarchy, the number of times through the game, and proficiency level. The model records vocabulary and grammar capabilities and is constantly updated as the student progresses through the program.

2. Introductory Phase

During the introductory phase, the student performs tasks that indicate his ability to use the keyboard, mouse, and a touchscreen (when one is used). The purpose of this game is to make sure that the child is as proficient in the first diagnostic test as he is on the last diagnostic test. This keeps a lack of familiarity with a computer from skewing tests that are supposed to measure proficiency with letters and words.

The games include a tracking game like *Neko* where a mouse character is moved around the screen with the computer mouse. As the mouse runs, a cat chases it. This game gets the child used to moving the cursor and following it with his eyes.

Another game uses a spinning wheel that stops when a specific key is pressed on the keyboard. An owl, one of the guide characters in the game, tells the child to press the "D" and a picture of a keyboard appears with a flashing square where the "D" is. Another time Owl tells him to press the space bar, another time it is the enter key. The goal is to get the student comfortable with the keyboard.

Tic-tac-toe is used to familiarize the student with the touchscreen. The child learns that he can mark squares by touching them as he plays against the computer. This game only appears if the program detects a touchscreen.

The final game in the diagnostic set has the child building things with colored blocks. This is a free form game and it gives the child practice in clicking, dragging and dropping objects with the mouse.

The goal of these games is to insure that the child knows how to use the controls before evaluating his responses to the optional screens in the next phase.

3. Evaluation Phase

The intent of the evaluation phase is to determine two things; the knowledge the student already possesses and, more importantly, the hierarchy of the seven intelligences at work in the child.

The results of the diagnosis is processed by the diagnostic expert to design all aspects of the individual lesson plan. This is where the core games and paths are modified to appeal to the special intelligence profile of the student. This includes the screen design, the use of sound and music, the type of guide, or helping character, as well as the starting difficulty levels. This process is described in Section 4 below. The diagnostic phase is only run once per child. Data for further modifications are collected during the regular program.

The method for evaluating the student's desires and skills is having the student walk through a series of settings on a trail that forks. Each fork shows two very different scenes. For example, one fork shows a party going on in a small house. The party has lots of activity and many people. The other branch shows a forest clearing with one small animal and very little activity. This choice helps indicate whether the child is interpersonal (party) or intrapersonal (forest).

If the child chooses the party, he is greeted by one of the party characters. The character asks which game the student wants to play. One game is musical, asking the student to repeat rhythms by tapping the space bar. Another challenges him to complete a maze. A third is a dot-to-dot puzzle using letters. The choice indicates what kind of activity is most interesting to him. Based on the first assumption in section A above, this indicates

the dominant intelligence. For example, if he chooses the musical game, his dominant intelligence is music. If he chooses the maze, his dominant intelligence is spatial.

After the student finishes the game, he is asked if he wishes to play the same game again or one of the others. After he completes the second game his host asks the student to leave the party and walk further down the trail.

If the child chooses the forest clearing, the activity level is much lower. Instead of a child talking to him, the owl is up on a branch. This owl is the child's guide, or tutor. The child watches the small animal, a puppy, chewing on a bone. After a few seconds, the owl asks the child what kind of game he wants to play. The first choice is to find letters in the trees and grass. The second is to match the puppy's barks by pressing the space bar, measuring the childs ear for rhythm. The third is a spatial relationship game like the maze in the diagnostic games. As in the party scene above, the student is given the choice to play the same game or one of the others. After he completes the second game, the owl tells him that it is time to walk down the trail.

There are several more choices like these during the diagnostic phase. The choices provide the diagnostic expert with the data to determine the profile of the student's hierarchy of intelligences.

4. Produce the Lesson Plan

At this point the diagnostic expert has the information to build the intelligences profile. The diagnostic expert assigns weights to each intelligence and use these weights to determine the most effective method for presenting the lessons to the students. The teaching expert uses the assessments of the student's proficiency to determine the beginning difficulty level.

With the advent of object-oriented programming, it is now possible to write a program that can easily add or remove graphic elements, or objects, to the screens. Using this technology enables the teaching expert and the game generator to extensively modify the screens to support the student profile. Because the objects can establish their own

communications and command links as required, the programmer does not have to anticipate and program code for every eventuality. The teaching expert chooses options that involve more than one intelligence at a time whenever possible.

For example, the game description below is written for a child that was determined to have a dominant intrapersonal intelligence with a strong spatial influence. The guide is an owl instead of a person and other characters are kept to a minimum. This is in keeping with the intrapersonal person's inclination to work things out inside themselves instead of working with other people. Selecting letters and words is done with a mouse instead of using the keyboard to involve the spatial relationships on the screen instead of the letter aspects of the keyboard that would appeal more to a linguistic child. The scenes have less activity to appeal to the intrapersonal childs desire for secretive places. All of these are adjusted by the teaching expert in accordance with programmed rules about what appeals to the different dominant intelligences. These aspects are then adjusted by the teaching expert as it monitors the progress of the student as he plays the game.

5. The Game

This section explains the learning games in each season. The seasons, spring, summer, fall and winter, represent different sets of skills. For example, in winter the skill block is sentence structure and each game develops knowledge about sentence construction. The theme of the seasons was chosen because it is something that all children are familiar with. Even children that have lived their whole life in a warm climate have read stories or seen shows that describe fall and winter.

As stated above, this game was developed for a child with a dominant intrapersonal intelligence with a strong spatial influence.

a. Spring

After the diagnostic phase Owl tells the student that it is time to begin the quest. The first game the child comes to is a vocabulary-building exercise. Since the child in this example responded to and chose images that were less active, the screen shows a

simple meadow with a few flowers. The student is presented with a text box at the bottom of the screen with outline letters that spell out a prize. Owl tells him that he must find the letters hiding in the meadow and put them on the matching spaces. This exercises pattern matching and letter recognition. As the letters are added to the word, the computer pronounces the sounds, building up to the word. When the word is completed a picture of it appears on the screen and Owl pronounces the word and invites the student to repeat it. This task appeals to the spatial, linguistic, and to a lesser extent the kinesthetic intelligences.

The next round replays the game with a slightly longer word. This reinforces the lesson and adds to the child's confidence. The teaching expert monitors the time it takes for the student to complete the words. As the student fills in the word more and more quickly, the letters get harder to find. The objective is to keep the student concentrating on the game while increasing the vocabulary. When the speed starts to drop off, indicating that the game has become too hard, the next scene becomes easier. If the speed continues to drop off, the teaching expert decides that the child is bored and Owl encourages him to move to the next task, telling him that there are other games waiting for him.

Further down the path, the student finds a cottage hidden in the trees. Inside the cottage he finds two shelves on the wall. Owl, sitting in the window, explains that the object of this game is to match the capital letters on the top shelf with the lowercase letters on the lower shelf. A capital letter is then highlighted and Owl asks the student (by name) to click the matching lower case letter. The early stages of this game only have a few letters at time. As the student progresses, he will get more letters at a time.

The third game on this level uses the first letter to identify objects. In a barn the student is presented with a letter and asked to identify objects that start with the letter. Owl pronounces the names of the objects if the student clicks Owl's tummy. As he pronounces the name, the object blinks and the student is asked if the word begins with the letter.

When he completes three games, one game three times or three different games, the student is awarded a key. When he is awarded a key, a door into summer appears in the upper left hand corner. Owl congratulates the student and informs him that he can proceed to the next level, summer, any time he is ready. He does not have to leave the current season until he is ready, and he can return to any previous season he left by walking back through a door in the lower left corner.

As explained above, each time the student completes a game he receives a prize. He can keep the prizes in a knapsack and take them out when he wants to look at them by clicking on the flap of the sack. Between tasks, the student is able to go to his clubhouse and take the prizes out and store them on a shelf.

The clubhouse is also a place that the student can go to hear a short story. After he has completed his games and earned his key to open the door to the next season the child can ask Owl to read him a story. Owl reads a story that appears on an open book in the clubhouse. The words highlighted as Owl says them and there are some animated graphics to help build the student's vocabulary.

The student is also able to play the games that were in the diagnostic phase. The teaching expert monitors how much time he spends playing these games instead of doing lessons and locks up the games if he plays too much and tells him to return to the other games.

b. Summer

In the summer level the student deals with whole words. The student is presented with a group of objects and words. The goal is to match the words and objects. At first, Owl says the word and asks the student to put the object on the word. If the student does not put the object on the correct word, it goes back to its original position and Owl says the word again. If he still picks the wrong word again, the correct word flashes. In this manner, the student gets used to matching the sounds to the words and having them reinforced with images. If the student was determined to have a strong musical intelligence,

and if the computer system has an adequate sound board, then the words will be pronounced in a lyrical manner. By giving the syllables a musical intonation, the musical student is better able to remember the sounds and the spellings. A simple song related to the word may be played to help the child remember the word.

Another challenge on the path is a castle room with letters printed on the bricks in the wall. The challenge is to connect the letters using the mouse or touch- screen to make words. The lines will form a picture as in a dot to dot. The spatial relationships help the student remember the word later.

The next task is similar. In this room the student is provided a list of words in a long picture frame. A tapestry hanging on the wall is full of letters. The student is to find the words in the picture frame in the word jumble on the tapestry. In this first level the jumble is only six letters across and the words are very small. This makes it easy for the starting reader. If the student can't find them they are highlighted. After the student finds all the words Owl asks him if he wants to play again. If he does not he can go back on the trail and play any of the games in the summer level. If he has finished playing the games on this level he can move on to the fall level.

c. *Fall*

In this season the student plays word games. The first game is criss cross, a crossword puzzle that uses spaces and a list words that fit in the spaces instead of clues. The student is presented with interconnected horizontal and vertical rows of boxes, just like a crossword puzzle without the numbers. He is also given a list of words, one word for each row. The only rule is that the letters must match at the intersections. If the child has problems, then a letter in an intersection point flashes and the matching letter in a word on the list also flashes. The student drags the word to the proper box and drops it in. He wins the game when he fills the puzzle. As this game gets more difficult, it is harder to fit all the words in and harder to earn the prize.

A second game on this level has letters or phonograms on stones. The stones are in a jumbled mess. The game is to make the greatest number of words possible. The student uses the mouse to select stones and move them down to a row at the bottom of the screen. As a stone is selected and moved, another stone with the same letter of phonogram takes its place. When the student completes a word he presses the enter key. If the word is correctly spelled, it is added to a list to one side of the screen. Depending on the game level and the student's skill level, as assessed by the diagnostic expert, a minimum number of words is established. When the student makes the minimum number of words he is awarded a prize. Various levels of help are available, such as highlighting the incorrect letter or letters in a word, highlighting the correct letter in the pile, Owl may say a possible word, and even a list of possible words, with missing letters, on the screen.

The third game in the fall scenes is a spelling game that makes the student use the keyboard or the mouse. The student is provided a simple picture and Owl tells him to spell the word by choosing branches in the forest (or roads in a town or train tunnels). Each path choice is marked by a letter. For example, the picture at the top of the screen is a dog. The trail forks with one side marked with a "b" and the other marked with a "d." If the student chooses the path marked with a "b" (by clicking on the sign with the letter) he walks on that path. Very soon he finds a large tree lying across the path and Owl tells him that he must go back and choose the other branch. In cases were there is more than one choice left, Owl says "one of the other paths." When he chooses the "d" he comes to a another fork after a short walk. This fork has three letters: an "a," a "t" and an "o." At this point the "d" appears by the picture and Owl asks him, "which letter comes next?" If he chooses an incorrect path he again runs into some kind of road block. As the student gets better at this, the words get more difficult and the incorrect choices are phonetically closer to the correct choice.

A simple crossword puzzle using icons for clues will be the fourth game. As with criss cross, a list of words is provided and the student clicks and drags the word to its place in the puzzle.

After completing three games, the student is able to pass on to the next level, winter. The theme of winter is sentence structure.

d. Winter

The first game works on the difference between nouns and verbs. The student is shown pictures of objects such as snowballs, books and apples, and animated pictures of people and animals doing things like skiing, running and flying. The word depicted by the pictures is written under the picture. Owl shows the student two boxes. One is marked "Things" the other is marked "Doing." The student is told to click the object and drag it to the box he believes that it should go in. he chooses incorrectly, the picture returns to the spot it was at. At the end, Owl explains that action words are verbs and thing words are nouns. As the difficulty increases, the classes of words are increased to adverbs, adjectives and pronouns.

The second game works on punctuation. The game starts with spaces, question marks, exclamation points and periods. Owl explains the use of sentence endings and illustrates it by reading sentences to the student. Then the question "Are you hungry?" appears and Owl asks if the sentence is telling something or asking something. As Owl is asking this, the period and the question mark are highlighted in turn. The student is asked to click the proper punctuation mark. These questions get more complicated as the student progresses.

The third game is a variation of the classic word game, "Hangman." The student is shown a picture with blank spaces below it. Owl tells him to guess the letters in the word. For each letter the student gets correct, a part of a snowman appears. A new word appears as the student completes one, adding more features to the snowman.

The fourth game in winter is a maze game. In this game the student is presented with four words with images. Owl tells him to chose a word. The choice takes him to another set of paths with four more word choices. As he chooses the words, they are

moved to the bottom of the page. In this way, the student creates his own simple sentences. When he finishes the sentence, Owl reads the sentence to him.

After completing this phase, the student will be able to return to spring and begin the next level. As he completes levels he will be awarded points. As he accumulates these points, will be awarded a series of titles or ranks, such as tenderfoot, scout, trailblazer, etc.

6. Desired Results

CAPER tutors students in reading. The program keeps a record of the words that the student learns as well as his knowledge of sentence construction. CAPER provides each student an individual lesson plan that is tailored to his dominant intelligences and preferred learning style. The teacher can have a report on how much the students learn and how quickly. While these reports are useful, evaluators will have to remember that as far as the children are concerned, they are playing a game and the learning is accidental. Their priorities may not match the priorities of the scoring system.

C. DISCUSSION

Researchers have only recently determined that children learn to read in many different ways. Research has indicated that one-on-one tutoring is capable of raising student performance from a median range of 50% to 60% to a mean of 98%. (Woolf 88, p. 2) One teacher to 20 to 30 students cannot provide one-on-one tutoring. CAPER can.

CAPER provides students with an individual lesson plan. Teachers that teach 20 to 30 students cannot possibly teach each one in a method optimized for that particular child. A well written program can. The teacher cannot keep a progress report on each child with the same level of detail that the computer can. The teacher often makes subjective judgements without having the detailed data to support his decision. Using CAPER, he will have a detailed record that can be used to form much more informed opinions. This gives the teacher's recommendations to the parents and the student even greater weight than it has now.

A program like CAPER is only possible now when so many research efforts and emerging technologies are coming together. Research in learning and education are documenting not just the differences in learning styles, but also the most effective way to teach children with different learning styles. Researchers in the field of artificial intelligence (AI) have developed several expert shell systems that are suitable for this kind of analysis: many details and connections in a limited domain. Object-oriented programming techniques now enable programmers to write code with tremendous adaptability because of the ability of subsequent screens to inherit the modifications of previous screens. This means much less coding and much less code. For the first time, sophisticated tutoring programs can be written to run on what is emerging as the average computer system.

CAPER cannot replace the teacher. He is still needed to make sure that learning is taking place. Teachers have to help the student at times and be there for the student to show off to. But CAPER can relieve teachers of many tedious tasks. The program can exhibit the infinite patience that people cannot. But the teacher is still the best one to decide when patience is not the best solution. CAPER is a very valuable tool, but any tool is only as good as the people that are using it.

D. SUMMARY

CAPER has shown one method of providing one-on-one tutoring to a large number of students. It does not solve all reading problems and it does not replace human teachers and reading specialists. But, if used properly, CAPER will get the majority of children that are currently labeled "learning disabled" out of the special education classes and back in the mainstream where they belong. It will do this because it can change its teaching style to meet the needs of the students with dominant intelligences, and therefore learning styles, that do not match the majority in that classroom. The teacher cannot. This program can be all things to all students. The teacher cannot. It will help teach a critical and complicated skill to many different students in many different ways. This powerful tool will improve

many students' attitudes about reading. Making learning to read fun will help make reading fun.

VII. CONCLUSIONS AND RECOMMENDATIONS

The purpose of this thesis was to develop a software model to help children that are labeled "learning-disabled" learn to read. This chapter provides a summary of the contributions of this thesis and discusses recommendations for future research.

A. SUMMARY OF CONTRIBUTIONS

While there are many educational software packages available for children, very few have been developed specifically for the child that is labeled "learning-disabled." Most packages appeal to the student who is already doing well in school. Development in the area of learning-disabilities is in it's infancy. The research and development currently being done acknowledges a problem with the child and develops the software around the problem. This thesis took the approach that most of the children labeled "learning-disabled" do not have a learning problem, they just have a different learning style than most schools or software packages use. This thesis outlined the necessary components needed in a software package to help teach a child to read regardless of their learning style.

Ideas have been organized and structured in a new way to allow a starting point for software development using the many differing learning styles. A sample program, CAPER, has been described to illustrate the implementation of these newly organized concepts.

CAPER brings together developments in the following three areas of research. Advancements in the field of artificial intelligence provides the expert systems shell that are capable of evaluating data, reaching conclusions and implementing decisions. Developments in object-oriented programming greatly reduce the overhead required to modify the core program on the fly, making possible the detailed tailoring of the core program that enables students of such vastly different needs to have their needs met by one

program. Finally, the research in how people learn provides the direction to build a program that can identify the types of intelligence at work and show how to teach that intelligence.

This concept of teaching to the user's learning style can easily be expanded to other areas besides reading. It can be used for math, science, social studies or in any area the developer perceives a need.

B. RECOMMENDATIONS FOR FUTURE RESEARCH

This thesis has provides a framework for development of software to help children with varying learning styles learn to read. The ideas presented need to be implemented in a program and then tested and analyzed with children of all learning styles. Based on the results of this testing, refinements can be made to allow the program to be a tool any person can use to learn to read.

Two of the three assumptions in the sample program (p. 67) should be proved or disproved. The most important one is the first assumption, that children will first choose to do that which they do best. This assumption drives the entire program tailoring process and will greatly lessen the effectiveness of the program if it is not true. The third assumption that involving more than one intelligences at a time is always preferable to involving only one is of interest, but it is not critical. If it is not true, then the screens can be simplified without lessening the effectiveness, but the program will work fine as it is.

As current technology becomes more accessible to more schools and families, it will become easier to address more of the learning styles due to the expanding system capabilities while keeping the software in a form that will be readily available to users.

APPENDIX A

SEVEN KINDS OF LEARNING STYLES (ARMST 93)

A Child who is strongly:	Thinks	Loves	Needs
Linguistic	in words	reading, writing, telling stories, playing word games etc.	books, tapes, writing implements, paper, diaries, dialogue, discussion, debate, stories etc.
Logical-Mathematical	by reasoning	experimenting, questioning, figuring out logical puzzles, calculating etc.	things to explore and think about, science materials, manipulatives, trips to planetarium, science museum, etc
Spatial	in images and pictures	designing, drawing, visualizing, doodling etc	art, lego, video, movies, slides, imagination games, mazes, puzzles, illustrated books, trips to art museum etc.
Bodily-Kinesthetic	through somatic sensations	dancing, running, jumping, building, touching, gesturing etc.	role play, drama, movement, things to build, sports and physical games, tactile experiences, hands-on learning etc
Musical	via rhythms and melodies	singing, whistling, humming, tapping feet and hands, listening etc.	sing-along time, trips to concerts, music playing at home and school, music instruments etc.
Interpersonal	by bouncing ideas off other people	leading, organizing, relating, manipulating, mediating, partying etc.	friends, group games, social gatherings, community events, clubs, mentors/apprenticeships etc.
Intrapersonal	deeply inside of themselves	setting goals, meditating, dreaming, being quiet, planning	secret places, time alone, self-paced projects, choices etc.

Multiple Intelligences Summary Chart

	Core Components	Symbol Systems	High End-States
Linguistic	Sensitivity to the sounds, structure, meanings, and functions of words and language	Phonetic languages (e.g. English)	Writer, orator (e.g. Virginia Woolf, M.L. King)
Logical-Mathematical	Sensitivity to, and capacity to discern logical or numerical patterns; ability to handle long chains of reasoning	Computer languages (e.g. Pascal)	Scientist, mathematician (e.g. Madame Curie, Blaise Pascal)
Spatial	Capacity to perceive the visual-spatial world accurately and to perform transformations on one's initial perceptions.	Ideographic languages (e.g. Chinese)	Artistic, architect (e.g. Frieda Kahlo, I.M. Pei)
Bodily-Kinesthetic	Ability to control one's body movements and to handle objects skillfully	Sign languages, braille	Athlete, dancer, sculptor (e.g. Jesse Owens, Martha Graham, Auguste Rodin)
Musical	Ability to produce and appreciate rhythm, pitch, and timbre; appreciation of the forms of musical expressiveness.	Musical notational systems; Morse Code	Composer, performer (e.g. Stevie Wonder, Midori)
Interpersonal	Capacity to discern and respond appropriately to the moods, temperaments, motivations, and desires of other people	Social cues (e.g. gestures, facial expressions etc)	Counselor, political leader (e.g. Carl Rogers, Nelson Mandela)
Intrapersonal	Access to one's own feeling life and the ability to discriminate among one's emotions; knowledge of one's own strengths/weaknesses	Symbols of the self (e.g. in dreams, art work etc)	Psychotherapist, religious leader (e.g. Sigmund Freud, The Buddha)

Multiple Intelligences Summary Chart (continued)

	Developmental Factors	Ways That Cultures Value
Linguistic	"Explodes" in early childhood; remains robust until old age	oral histories; storytelling, literature etc
Logical-Mathematical	Peaks in adolescence and early adulthood; higher math insights decline after age 40	scientific discoveries, mathematical theories, counting and classification systems etc
Spatial	Topological thinking in early childhood gives way to Euclidean paradigm around age 9-10; artistic eye stays robust into old age	artistic works, navigational systems, architectural designs, inventions etc
Bodily-Kinesthetic	Varies depending upon component (strength, flexibility etc.) or domain (gymnastics, baseball, mime etc.)	craft works, athletic performances, dramatic works, dance forms, sculpture, etc.
Musical	Earliest intelligence to develop; prodigies often go through developmental crisis	musical compositions, performances, recordings, etc.
Interpersonal	Attachment/bonding during first 3 years critical	political documents, social institutions, etc
Intrapersonal	Formation of boundary between self and other during first 3 years critical	religious systems, psychological theories, rites of passage, etc.

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